PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
(Attorney Docket No. 006119.00010)

In the Application of:	)	
	)	
Scott Johnston, et al	)	
	)	Group Art Unit: 3624
Serial No.: 10/676,318	)	
	)	Examiner: T/B/D
Filed: October 1, 2003	)	
	)	Confirmation No. 6511
For: ORDER RISK MANAGEMENT	)	
SYSTEM	)	

PETITION TO MAKE SPECIAL

Assistant Commissioner for Patents
PO Box 1450
Alexandria, VA 22313

Sir:

Applicant respectfully petitions to make the above-cited application special for accelerated examination. The application was filed on October 1, 2003 and has not received any examination by the Examiner. The Patent Office is authorized to charge the required fee for this petition to make special as set forth in 37 CFR 1.17(i) to Account No. 19-0733.

I. PRE-EXAMINATION SEARCH

The Applicant hired a professional prior art search firm to perform a pre-examination search. A copy of each reference found in the search is attached. United States and foreign patents and published patent applications were searched electronically using the USPTO's on-site EAST patent image and full text system. Emphasis was placed on patents classified in the following class and subclasses:

CLASS 705	**DATA PROCESSING: FINANCIAL, BUSINESS PRACTICE, MANAGEMENT, OR COST/PRICE DETERMINATION**
Subclass 1	**AUTOMATED ELECTRICAL FINANCIAL OR BUSINESS PRACTICE OR MANAGEMENT ARRANGEMENT**
Subclass 35	**. Finance (e.g., banking, investment or credit)**
Subclass 36	**. . Portfolio selection, planning or analysis**
Subclass 37	**. . Trading, matching, or bidding**
Subclass 38	**. . Credit (risk) processing or loan processing (e.g., mortgage)**
Subclass 39	**. . Including funds transfer or credit transaction**

Electronic text-based searching of non-patent literature was also performed in the Association of Computing Machinery (ACM) Digital Library, General BusinessFile ASAP database, Proquest Databases, and Elsevier ScienceDirect database.

II. Present Application

Aspects of the present invention relate to trading methods and systems that utilize order risk data provided by traders. The order risk data may include order risk parameters, such as maximum delta, gamma and/or vega utilization values for derivative product contracts based on the same underlying product. A match system may then limit the trader's in-flight fill risks by tracking the trader's current order risk parameter utilization state and analyzing potential trades to determine how those trades will impact the trader's order risk parameter utilization state. The match system may also limit cumulative risks by canceling orders after an order risk parameter utilization state has been exceeded.

II. DETAILED DISCUSSION OF REFERENCES

The following is a detailed discussion of the references, which identifies with the particularity required by 37 CFR 1.111 (b) and (c), how the claimed subject matter is patentable over the references.

U.S. Patent No. 5,649,116

This reference discloses a computer-based system for managing risk among a plurality of accounts, each account having an associated account exposure, has a means for submitting a transaction to a selected account of a plurality of related accounts and a monitoring means, responsive to the submitting means, for determining a combined exposure of the plurality of related accounts associated with the selected account that would result from the submission of a transaction. A means, responsive to the monitoring means, is provided for authorizing the transaction when the combined exposure determined by the monitoring means is less than a first predetermined limit and for denying a submitted transaction when the combined exposure would exceed the first predetermined limit if the transaction were to be authorized. A means is provided for alerting a first officer when the combined exposure determined by the monitoring means would exceed a second predetermined limit if the transaction were to be authorized. A means is also provided for receiving from the first officer an authorization indicia to the authorizing means and for causing, upon the authorizing means receiving the indicia, the authorizing means to authorize a previously denied transaction. Means are also provided to assess charges for the use of daylight overdraft funds.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a

derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent No. 5,799,287

This reference discloses a method and apparatus for determining an optimal replicating portfolio for a given target portfolio involves an initial step wherein a user defines a target portfolio to be replicated, a set of available market instruments from which the replicating portfolio may be created, a set of future scenarios, a horizon date, and a minimum profit to be attained. A representation of the trade-off between risk and expected profit for some arbitrary replicating portfolio is then determined and used to calculate a maximum risk-adjusted profit. The maximum risk-adjusted profit reflects that level of return that may be achieved with an optimum degree of risk; that is, it reflects that point in the risk/reward trade-off where a marginal cost of risk is equivalent to a marginal benefit attainable by assuming that risk. The method then uses the predefined set of available market instruments to identify a set of transactions that will create a replicating portfolio that will achieve the maximum risk-adjusted profit. The method and apparatus also derives the information required to compute a risk premium for pricing of portfolios in incomplete markets, and performs the computation.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent No. 6,061,662

This reference discloses a Monte Carlo system and method for the pricing of financial instruments such as derivative securities. A path-integral approach is described that relies upon the probability distribution of the complete histories of an underlying security. A Metropolis algorithm is used to generate samples of a probability distribution of the paths (histories) of the security. Complete information on the derivative security is obtained in a single simulation, including parameter sensitivities. Multiple values of parameters are also obtained in a single simulation. The method is applied in a plurality of systems, including a parallel computing environment and an online real-time valuation service. The method and system also have the capability of evaluating American options using Monte Carlo methods.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent No. 6,317,727

This reference discloses a credit monitoring system in an electronic trading system forms a complex check to determine if two particular counterparties will except each other for a particular trade based upon their respective predefined credit preferences. In accordance with an embodiment, credit preferences imputed by each counterparty with regard to the other counterparty are referenced to determine the trade eligibility of either party with respect to the other for a particular financial transaction instrument. Indication of whether a counterparty can enter into the proposed trade is conveyed to the respective trader, preferably using a color coding scheme in which various colors represent the relevant credit status with regard to the viewing trader. The complex check performed by the system may be embodied in a simple yes/no statement, in terms of maturity of a particular financial instrument, or in terms of a risk quotient (i.e., risk equivalent or RQ) initially determined by the system, though modifiable by the trader.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent No. 6,418,419

This reference discloses an apparatus and method of automatically and anonymously buying and selling positions in fungible properties between subscribers. The specific embodiment described in the disclosure relates to the buying and selling of securities or contracts where the offer to purchase or sell the property may be conditioned upon factors such as the ability to purchase or sell other property or the actual purchase or sale of other property. Specifically, the system described includes methods by which the system will sort and display the information available on each order, methods by which the system will match buy and sell order and attempt to use other markets to effect the execution of transactions without violating conditions set by the subscriber, methods by which the apparatus will execute transaction and report prices to third parties such that the user is satisfied and short sales are reported as prescribed by the rules and

regulations of the appropriate regulatory body governing each subscriber in the associated transaction. A communication system is described which allows subscribers to communicate anonymously for the purpose of effecting transactions in such property under such conditions.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter…"

U.S. Patent No. 6,622,129

This reference discloses a method of creating an index of residual values for leased assets such as vehicles, transferring residual value risk, and creating lease securitizations. The index of residual values includes valuation information pertaining to different types of vehicles, different models and submodels of vehicles, different combinations of vehicle options, different vehicle model years, etc. The residual value index is updated with subsequent valuations of the leased assets and is employed to facilitate the transfer of residual value risk and create lease

securitizations via mechanisms such as residual value futures, options, bonds and insurance products.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2001/0056398

This reference discloses a method and system for delivering foreign exchange risk management advisory solutions to a designated marked . For each user, the disclosed system generates an exposure model that is consistent with that user's risk management policy and a budget/pricing determination made in response to user information and external pricing information. The disclosed system may further operate to determine an appropriate measurement of risk and associated hedge alternative for a user, consistent with economic forecasts, and process a request for a hedge instrument from the user. Various hedge instruments may be analyzed and/or obtained through the disclosed system, including spot contracts, forward

contracts, option contracts, and money market instruments. The disclosed system further provides extensive training, compliance and sales related features.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0046151

This reference discloses an interface primarily used in computerized trading processes. In the especially preferred embodiments, the interface comprises a first sub-interface that allows "plug ins" to be dynamically created and/or edited. The plug ins are executed by a logic engine in which uses various inputs and outputs to obtain necessary information, process the order, and execute the order. The interface can additionally comprise a second sub-interface used to track orders, as well as a third sub-interface used to monitor orders.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0049661

This reference discloses an open-ended apparatus, methods and articles of manufacture for constructing and executing transaction processes and programs. These apparatus, methods and articles of manufacture are primarily used in computerized trading processes. In the especially preferred embodiments, transactional algorithms may be dynamically created and used through "plug ins," which are executed by a logic engine in which uses various inputs and outputs to obtain necessary information, process the order, and execute the order.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0073007

This reference discloses a system, method, and computer program product for pricing options which involve more than one underlying asset. The method employs a lattice approach by extending current trinomial techniques to higher dimensions, while achieving a maximum economy of nodes. Such economy produces computational advantages in terms of faster execution speed and the utilization of less memory resources. The method valuates options under a general form (i.e., Brownian motion) where parameters may depend on time and price, and accounts for drift and volatility parameters.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0082967

This reference discloses an automated trading exchange having integrated quote risk monitoring and quote modification services. An apparatus is implemented using at least one computer, having memory, and a processor. The computer is configured to receive orders and quotes, wherein specified ones of the quotes are contained in a quote group, and have associated trading parameters such as a risk threshold. Not all received quotes are required to have trading parameters as described herein. Preferably, the quote group contains all the quotes, or a subset of quotes, belonging to an individual market-maker for a given class of options contracts, or possibly the quotes of two or more market-makers that have identified themselves as belonging to a group for the purposes of risk monitoring and quote modification. The computer typically generates a trade by matching the received orders and quotes to previously received orders and quotes, and otherwise stores each of the received orders and quotes if a trade is not generated. The computer then determines whether a quote within the quote group has been filled as a result of the generated trade, and if so, determines a risk level and an aggregate risk level associated with said trade. The computer then compares the aggregate risk level with the market-maker's risk threshold, and if the threshold is exceeded, automatically modifies at least one of the remaining quotes in the quote group. The computer may also automatically regenerate quotes that have been filled.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0099651

This reference discloses a credit monitoring system in an electronic trading system forms a complex check to determine if two particular counterparties will except each other for a particular trade based upon their respective predefined credit preferences. In accordance with an embodiment, credit preferences imputed by each counterparty with regard to the other counterparty are referenced to determine the trade eligibility of either party with respect to the other for a particular financial transaction instrument. Indication of whether a counterparty can enter into the proposed trade is conveyed to the respective trader, preferably using a color coding scheme in which various colors represent the relevant credit status with regard to the viewing trader. The complex check performed by the system may be embodied in a simple yes/no statement, in terms of maturity of a particular financial instrument, or in terms of a risk quotient (i.e., risk equivalent or RQ) initially determined by the system, though modifiable by the trader.

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1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0120542

This reference discloses a method and system for hedging a correlation risk associated with a basket option that includes a plurality of securities that includes the step of selecting at least two of the plurality of securities and, in the next step, forming a best-of option for the at least two of the plurality of securities. Finally, the best-of option is combined with the basket option to hedge the correlation risk associated with the basket option.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2002/0174056

This reference discloses a system for providing options trading data. The system includes an options data system storing options data, such as options that are presently available to be bought or sold in an options marketplace. The system also includes a user profile system that stores user profile data, such as data that indicates the user's aversion to risk. An options selection system connected to the user profile system and the options data system generates options trading data, such as by selecting options that are presently available based on the user's aversion to risk. In this manner, a user with limited options trading experience can be provided with options trade suggestions that match the user's risk preferences.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a

derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No.2003/0009419

This reference discloses a system for processing trade data and market data to produce risk management reports and delivering reports, simultaneously, to multiple related and unrelated users over a distributed network. In one aspect of the invention, the risk management analysis includes the assessment of risk through mark-to-market, profit and loss, "greek", FAS 133, and related reports. Further, market and trade data may be collected electronically from exchanges, information service provides, and other sources to be aggregated for use in the risk management analysis

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2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0033240

This reference discloses a computer implemented method for negotiating contracts between a plurality of participants. An order is received from a first participant of the plurality of participants. Position risk of the first participant is calculated by accessing data regarding the first participant and using the data regarding the first participant in a parametric variable equation modified by control values from a simulation model, to calculate the position risk of the first member. The order is blocked, if the position risk of the first participant is in a first condition for the first participant. The order is made available for forming into a contract, if the position risk of the first participant is in a second condition for the first participant.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0046218

This reference discloses novel options-based financial instruments, and a related system and method that automates market trading of the novel instruments. The invention protects positions against short-term market movements by inducing users on the opposite sides of a transaction to trade in equal or near equal dollar volumes. The system includes an automated price quotation capability for the instruments, that operates at computer speeds, without human intervention--specialists and market makers are not necessary. Through the use of feedback techniques, the system induces traders on the opposite sides of a transaction to trade in near equal numbers of round lots, minimizing the system's financial exposure from unbalanced trading. The system also fully automates the trading of the financial instruments themselves, plus the attendant functions (inventory control, billing, reporting, etc.), so that users may interact with the system on-line, without human intervention. The novel financial instruments have the characteristic that they allow trading directly in the price movement of the underlying security (stock, bond, currency, etc.), while providing superior financial leverage as compared to investing directly in the underlying security.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0069821

This reference discloses a risk management system for use in generating, for any long or short stock position or an entire portfolio, one or more options hedging strategies to protect unrealized profits and to insure the position against directional market risk. The risk management system recommends a preferred options hedging strategy out of many possible strategies based on minimizing losses while maintaining profits, but users of the system can review other possible strategies and make their own selection using predetermined reward, cost, and risk goals. In addition, user's can modify the predetermined goals in a real-time mode and assess alternate options hedging strategies. The risk management system also monitors existing investor profiles and alerts the user when a hedging action is recommended based on pre-established parameters customized for a particular stock position or an entire portfolio. The system accomplishes these features, and others, through an easily learned, fast and efficient user interface.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0074167

This reference discloses a method and system for simulating changes in volatility for a price of a particular option on an underlying financial instrument. A volatility surface model having at least one surface parameter is provided along with a set of volatilities for a plurality of options on the underlying financial instrument. The set of volatilities is analyzed to determine an initial value for each surface parameter which, when used in the surface model, defines a surface approximating the set of volatilities. The values of the surface parameters are then evolved using an appropriate evolution function. A volatility value for a particular option is extracted from the volatility surface defined by the evolved surface parameter values. The extracted volatility value can then be used in an option pricing model to provide a price of the particular option. The volatility of a basket options valued relative to the performance of multiple components can be simulated by determining the value of surface parameters for options on the component securities

and then combining the component surface parameters to determine surface parameters for a volatility surface of the basket.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0093347

This reference discloses a software application program, executed by a processor of a digital data processing device, to analyze and model economic/financial risk associated with sovereigns, financial sectors, non-financial sectors, and/or investment portfolios. The disclosed technology can calculate and assess, for example, contingent claim values, asset values, volatilities, default barriers, and monetary parameters from financial and macroeconomic data associated with government and monetary authorities and can use such calculations to calibrate risk models and generate economic balance sheets for an economy useful in valuation, risk and

vulnerability analysis, risk mitigation, design of investment strategies, and policy analysis and design.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0097328

This reference discloses in an automated exchange system a separate virtual derivative instrument used in the matching process of the system. The reference instrument, i.e. the instrument in which derivative contracts are traded, is then preferably displayed together with the hedged derivative instruments. The reference instrument, i.e. the underlying contract, is presented with a price. The matching of the virtual hedged derivative contract can take place in a matching module of the automated exchange system. The trade can subsequently be captured in a separate module of the system where the combined deal is formed. When a trade in a virtual hedged derivative instrument is matched in the matching process of the system, the match is reported to a

subsequent deal capture module where the corresponding different deals of the virtual hedged derivative contract the reference instrument are formed. The deals formed in the deal capture module do not need to be matched, since the number of contracts and the price can be deduced from the information relating to the virtual hedged derivative contract.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

<u>U.S. Patent Publication No. 2003/0101123</u>

This reference discloses a system, method, software, and portfolios for managing risk in markets relating to a commodity delivered over a network are described, in which a market participant constructs portfolios of preferably liquid price risk instruments in proportions that eliminate the Spatial Price Risk for the market participant's underlying position. Techniques are also disclosed for constructing and evaluating new price risk instruments and other sets of positions, as well as identifying arbitrage opportunities in those markets. In particular, a "deltas

vector" is calculated concerning a portfolio of future positions and derivative contracts, wherein the "deltas vector" is the partial derivative of the market participant's net market position taken with respect to the forward shadow prices .lambda. of the network which depend upon congestion in the network. The "deltas vector" can then be used to simplify the valuation of a derivative contract, develop a hedging strategy, evaluate a hedging strategy with respect to congestion, identify a successful bidding strategy at auctions of derivative contracts, and determine an optimal position in a multi-settlement nodal market. Moreover, techniques are also described for evaluating the matrix of Power Transfer Distribution Factors and loss factors (comprising the A matrix) that are needed to estimate the "deltas vector".

This reference does not teach or suggest at least:

1. “receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter” and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. “transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter” and executing a derivative product order when the trader’s current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader’s current order risk utilization state at a first exchange and at a second exchange and “transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter…”

U.S. Patent Publication No. 2003/0101125

This reference discloses a derivative security whose value is determined by whether an underlying instrument will trade above or below a given price at or by a given time. The price of the underlying instrument in the inventive instrument must move a certain amount in a certain direction in a limited amount of time. If it does, that trade yields a fixed amount of money for the acceptor of the contract. If it does not, that acceptor loses the premium lie paid for the contract.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0208430

This reference discloses a method for providing a bid price and/or an offer price of an option relating to an underlying asset, the method including the steps of receiving first input data corresponding to a plurality of parameters defining the option, receiving second input data corresponding to a plurality of current market conditions relating to the underlying value,

computing a corrected theoretical value of the option based on the first and second input data, computing a bid/offer spread of the option based on the first and input data, computing a bid price and/or an offer price of the option based on the corrected theoretical value and the bid/offer spread, and providing an output corresponding to the bid price and/or the offer price of the option.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0225648

This reference discloses a method of applying a substantially constant leverage to a value of a log-normal distributed asset includes providing an underlying log-normal distributed asset having an original volatility .sigma. and an original yield q. The asset includes an associated value S denominated in a currency having an associated interest rate r. The method and system

also include applying a leveraging factor L to produce a modified value, volatility and/or a modified yield.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2003/0233308

This reference discloses in automated exchange system, a single matching unit is supplemented with a calculation unit and a global memory accessible by both the calculation unit and the matching unit. Such a computer architecture will make it possible to perform some of the calculations related to the volume and/or prices of the baits needed in the matching to be performed in advance. The matching process is able to use the values resulting from the pre-calculation when needed, and since no or few calculations are done in one of the most critical parts of the system, i.e. the matching unit, the process of matching combination contracts can be performed at a much higher rate. Hereby the performance of the matching process will be

significantly increased. The provision of one or several calculation units will make it possible to perform even very complex calculations can be performed since most calculations need not be performed in real time.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2004/0044613

This reference discloses for a comprehensive risk evaluation of the electricity price fluctuations, respective relationships between power supplies or power demands and electricity prices are derived from data of historical power supply or power demand and data of historical electricity price for respective power exchanges, respective probability distributions of electricity price fluctuations relating to uncertain fluctuations of the power supply or the power demand are computed by using the respective relationships in a given period for evaluation of a market risk, the market risk of electricity price is measured by using the respective probability distributions of

electricity price fluctuations, a probability distribution for randomly fluctuating components is derived by Monte Carlo simulation, and a market risk to the electricity price fluctuations is evaluated.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2004/0064393

This reference discloses a computer-implemented method is provided for valuing and hedging payoffs that are determined by an underlying non-marketed variable that moves randomly. The value assigned is that which is obtained by projecting the instantaneous return of the future payoff onto the span of marketed assets. An explicit method is provided for determining this value by determining a suitable market representative. In a continuous-time embodiment, the methodology is based on an extended Black-Scholes equation that accounts for the correlation between the underlying non-tradable asset and marketed assets. Once this

extended equation is solved, the value of the payoff, the optimal hedging strategy, and the residual risk of the optimal hedge can be determined. In alternate embodiments, the same value is determined as the discounted expected value of the payoff, using risk-neutral probabilities for the non-marketed variable. These risk-neutral probabilities are again determined by the relation of the underlying variable to the payoff of a most-correlated marketed asset. The risk-neutral version of the method applies in both continuous-time and discrete-time frameworks, providing asset valuation, optimal hedging, and evaluation of the minimum residual risk after hedging.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter…"

U.S. Patent Publication No. 2004/0083158

This reference discloses methods and systems for providing network-based trading platforms with a continuous stream of up-to-date pricing date for derivatives by way of an externally based pricing-engine system. The pricing engine receives and process feeds of up-to-

date information to derive up-to-date pricing data for complex derivative securities. Preferably, the up-to-date information feed is received in real time from a network-based source. The methods and systems of the invention then write the derived pricing data to the locations in cache memory of a network-based trading platform where pricing data is read.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

U.S. Patent Publication No. 2004/0083165

This reference discloses systems, methods, apparatus, computer program code and means for gathering, organizing and presenting on a real time basis information pertinent to Risks associated with subjects related to the Construction Industry. Risks associated with the Construction Industry can be managed by gathering data relevant to the Construction Industry from multiple sources and aggregating the gathered data according to one or more Risk variables. An inquiry relating to a Risk subject can be received and portions of the aggregated data can be

associated with the Risk subject. The associated portions of the aggregated data can be transmitted to an entity placing the inquiry or other designated destination.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

Ritchie, Joseph; "Why Market Maker Position Limits Should Be Delta-Based"; *Futures*, Vol. 17, No. 9, PP. 42(2), August 1988; UMI Publication No.: 00415047

This reference indicates that a key economic function of position limits in markets should be prevention of excessive amounts of risk among participants who are not prepared to manage that risk. A method is proposed in which risk is delta neutral and "gamma balanced."

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

Meyer, Thomas O.; "Calculation and comparison of delta-neutral and multiple-Greek dynamic hedge returns inclusive of market frictions"; *Department of Commerce, International Review of Economics and Finance*;12 (2003); pp. 207–235

This reference describes research in which a model is developed that calculates position returns for both delta-neutral and multiple-Greek hedging effectiveness and incorporates Standard Portfolio Analysis of Risk (SPAN) margin requirements (MRs) as well as transaction costs (TCs).

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a

derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

Temple, Peter, et al; *World Reporter* (TM); Investors Chronicle; 11 December 1998; Copyright (C) 1998 Investors Chronicle; P. 62

This reference describes software that helps traders price options. A pricing model can determine implied volatility and various measures of sensitivity. Charting packages are also described.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

Holter, James T.; "It's Liquidity Stupid, CBOE Ups S & P Limits; *www.futuresmag.com*; November, 1996

This reference describes how the Securities and Exchange Commission (SEC) approved treating synthetic stock instruments, such as collars, as one instrument for hedge purposes. The SEC also approved increasing exercise and position limits as well as hedge exemptions at the CBOE.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

Kawaller, Ira G; "A novel approach to transactions-based currency exposure management"; *Financial Analysts Journal;* Nov/Dec 1992; 48, 6; pg. 79

This reference discloses an approach to transactions-based currency exposure management. The reference indicates that by buying options, where the consolidated delta of the

position equals the alternative futures hedge ratio, the hedger may be able to generate results superior to those of the traditional futures hedge in both rising and falling price environments.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

"S&P ComStock/Micro Hedge Windows: results rooted in reliability."; *Futures (Cedar Falls, Iowa); Annual* 1993 v22 n7 p26(1); COPYRIGHT Oster Communications Inc. 1993

This reference describes a fully networkable options analysis and risk management software product from May Consulting and S&P ComStock. The software allegedly allows continuous assessment of opportunities while minimizing risks, particularly when market prices are fluctuating. The reference indicates that Micro Hedge Windows offer theoretical values, delta, gamma, theta, four valuation models, implied volatility, volatility distribution, dynamic skew, trading sheets, sensitive variable analysis, profit/loss matrix and plot and derivatives.

This reference does not teach or suggest at least:

1. "receiving derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and processing a derivative product order in a manner determined by the derivative product order risk data and utilization data;

2. "transmitting to a first exchange first derivative product order risk data including at least one threshold value corresponding to at least one order risk parameter" and executing a derivative product order when the trader's current order risk parameter utilization value does not exceed the threshold value; or

3. determining a trader's current order risk utilization state at a first exchange and at a second exchange and "transmitting to one of the first exchange and the second exchange an offset value to adjust the at least one order risk parameter..."

Conclusion

The Applicants respectfully submit that the instant application is in condition for allowance. Should the Examiner believe that a conversation with Applicant's representative would be useful in the prosecution of this case, the Examiner is invited and encouraged to call Applicant's representative.

Respectfully submitted,

BANNER & WITCOFF, LTD.

Dated: 05/17/2004

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A Novel Approach to Transactions-Based Currency Exposure Management

Ira G. Kawaller, *Vice President-Director, Chicago Mercantile Exchange, New York*

In the traditional futures hedging situation, gains or losses due to price movement of the underlying exposure are offset by losses or gains in the futures hedge. The futures hedge effectively serves to lock in a price. This note demonstrates that, by buying options, where the consolidated delta of the option position equals the alternative futures hedge ratio, the hedger may be able to generate results superior to those of the traditional futures hedge in both rising and falling price environments.

Consider a U.S. investor who decides to buy British securities. At the time of the trade, the price of the securities is fixed in pounds sterling; but given traditional settlement and clearing conventions, the exchange of dollars for sterling would likely be deferred for some limited time (e.g., several days), exposing the trade to the risk of sterling strengthening in the interim.

Clearly, one way of dealing with this exposure is to initiate a long British pound futures position and maintain it until the trade date of the spot currency transaction. In this case, the hedge would offset either adverse or beneficial changes in the dollar-pound exchange rate, thereby making the hedger indifferent to exchange rate variability. Using options in a **delta-equivalent fashion** (i.e., where the consolidated delta of the option hedge equals the number of futures contracts required for the traditional futures hedge rate) provides an alternative that may be worthy of consideration. This **option hedge** alternative to the traditional **futures hedge** strategy offers the prospect of covering the risk and at the same time permitting incrementally superior results.

To illustrate, suppose the hedger in the above example substituted two **at-the-money** calls for each long futures contract required. As at-the-money calls have deltas equal to 0.5 or 50%, this option position should generate a result approximately equal to that of the futures hedge for small moves of the underlying pound futures price. Over more substantial exchange rate moves, however, the option strategy should provide a more attractive outcome. For example, if sterling strengthened (i.e., exchange rates moved adversely for the underlying exposure), the calls would become **in-the-money**, and each call's delta would increase above 0.50. As a consequence, the option hedge would start to generate greater profits than the futures hedge, allowing the option hedger actually to benefit from the strengthening of the British pound.

In the opposite market environment, with weakening sterling, the option strategy would again be more attractive. This time, the call would be moving **out-of-the-money**, and the deltas would be declining. The option hedge losses would thus be smaller than the futures hedge losses. Moreover, losses from the option hedge would fall short of the savings from being able to purchase the British securities at a more attractive exchange rate (i.e., with the weaker sterling), allowing for some overall benefit from a weakening British pound. Importantly, this strategy does not require an adjustment to the hedge ratio or the number of option contracts employed. That is, once the option hedge is initiated, it is maintained without adjustment exactly as long as one would otherwise maintain the traditional futures hedge.

As compelling as the advantages of this delta-equivalent option strategy may appear, however, the approach may not be unconditionally preferable. The qualification has to do with erosion of time value. Accepted nomenclature divides an option's price or premium into intrinsic value and time value. The intrinsic value is simply the difference between the option's strike price and the price of the underlying instrument, when this difference is beneficial (zero otherwise). The remaining portion of the option price, then, is time value. Time value reflects sensitivity to the market's perception of the degree of price variance expected over the remaining life of the option.

A basic characteristic of option prices is that, at the option's expiration, the premium should settle to a price equal to the option's intrinsic value; in other words,

Table I Option Hedge Outcomes

	Stronger BP (+2.0%)	*Weaker BP (−2.0%)*	*Stable BP (0.0%)*
Home Value of Securities (BP)	1,000,000	1,000,000	1,000,000
Initial Spot Ex. Rate ($/BP)	1.6000	1.6000	1.6000
Final Spot Ex. Rate ($/BP)	1.6320	1.5680	1.6000
Initial Futures Price (F1)	1.6000	1.6000	1.6000
Liquidation Futures Price (F2)	1.6320	1.5680	1.6000
Initial Call Price (C1)	0.0228	0.0228	0.0228
Liquidation Call Price (C2)	0.0418	0.0098	0.0222
Futures Results 16 ctr · (F2 − F1) · 62,500	$32,000	($32,000)	$0
Calls Results 32 ctr · (C2 − C1) · 62,500	$38,000	($26,000)	($1,200)
Dollars Paid Unhedged	$1,632,000	$1,568,000	$1,600,000
Dollars Paid w/Futures Hedge	$1,600,000	$1,600,000	$1,600,000
Dollars Paid w/Calls Hedge	$1,594,000	$1,594,000	$1,601,200
Calls Hedge Results Minus Futures Hedge Results	$6,000	$6,000	($1,200)

time value will ultimately decline to zero. In a stable environment (one where the underlying instrument's price—and thus the intrinsic value—is constant, and where implied volatility remains unchanged), time value will diminish as time passes, with the rate of decay accelerating as option expiration approaches. This being the case, the delta-equivalent strategy may be most appealing (1) for relatively short risk exposures (i.e., days rather than weeks or months), (2) when the expiration date of the option is not imminent and (3) when the implied volatility appears to be relatively low, or at least not excessively high.

With these caveats, then, for virtually any relatively short-term exposure where futures contracts may be used to manage price risk, the substitution of delta-equivalent long option hedges for futures contracts offers the potential of either greater hedge gains than exposure losses or smaller hedge losses than exposure gains—the best of both worlds.

An Example

Consider a U.S. stock trader who buys British securities. The terms of the trade require the payment of £1 million in four days. As normal interbank settlement practice for British pounds requires a trade date two business days before the desired value date for the currency conversion, the unhedged investor would bear two days of risk that the pound would strengthen.

At the time the hedge is initiated, options on British pound futures have 39 days remaining to expiration; futures have 49 days to expiration. Spot and futures exchange rates are assumed to be $1.600 per pound. The implied volatility of the call options is 11%; at-the-money calls are thus priced at 2.28 cents per pound.

Table I demonstrates three possible outcomes, depending on whether British pounds strengthen (+2.0%), weaken (−2.0%) or remain stable with respect to the U.S. dollar. A number of simplifying assumptions are incorporated. Specifically, the scenarios assume that a zero basis persists (i.e., the spot exchange rate remains equal to the futures price) and the implied volatility of the option stays constant over the life of the hedge at 11%. The futures hedge ratio is found simply by dividing the £1 million by the size of the futures contracts (£62,500 per contract); this hedge ratio is doubled for the at-the-money call hedge.

Glossary

▶*At-the-Money:*
An option is at-the-money if the underlying instrument's price equals (or approximates) the option's strike price.

▶*Delta-Equivalent Fashion:*
Where the results of the option hedge are designed to replicate the results of the futures hedge, assuming an instantaneous, incremental change in the futures price.

▶*Futures Hedge:*
The use of a futures position in combination with an existing exposure, where the futures contract is expected to generate gains when the underlying exposure is losing value or generating losses.

▶*In-the-Money:*
An option is in-the-money if it has intrinsic value. For a call, the price of the underlying instrument would be higher than the strike price; for a put, the price of the underlying instrument would be lower than the price.

▶*Option Hedge:*
The use of an option position in combination with an existing exposure, where the option is expected to generate gains when the underlying exposure is losing value or generating losses.

▶*Out-of-the-Money:*
An option is out-of-the-money if it has no intrinsic value. For a call, the price of the underlying instrument would be lower than the strike price; for a put, the price of the underlying instrument would be higher than the strike price.

S&P ComStock/Micro Hedge Windows: results rooted in reliability.

Micro Hedge Windows is a fully networkable options analysis and risk management software from May Consulting and S&P ComStock. The software allows continuous assessment of opportunities while minimizing risks, particularly when market prices are fluctuating. Micro Hedge Windows offer theoretical values, delta, gamma, theta, four valuation models, implied volatility, volatility distribution, dynamic skew, trading sheets, sensitive variable analysis, profit/loss matrix and plot and derivatives.

At the hectic FINEX, a division of the New York Cotton Exchange, floor trader Bennett Gordon puts a lot of stock in Micro Hedge Windows, the fully networkable options analysis and risk management software from May Consulting and S&P ComStock, his real-time market data feed vendor.

"Having an advantage is what it's all about," Gordon says, referring to his information system's dependability. "When the dollar was going haywire recently, we knew where our positions were and could respond immediately if necessary."

Micro Hedge Windows was designed by a former CBOE trader to offer traders like Gordon the ability to update positions automatically. With real-time updates, Gordon is assured of reducing his risk and achieving a seamless integration of information that is crucial for continuous evaluation of opportunities.

In Gordon's business, rapid price and volatility changes can stimulate opportunities, but only for traders who can act swiftly.

"Micro Hedge Windows provides me with the ability to manipulate data I get from S&P ComStock and download it into an Excel spreadsheet so that I can better evaluate my positions and make more strategic decisions," Gordon says.

To provide traders with optimal flexibility and total control, S&P ComStock has introduced OpenArc !TM^, an advanced workstation based on Microsoft !R^ Windows !TM^ graphical user interface. OpenArc allows traders to pull real-time information off the screen and integrate it into the Micro Hedge application; Micro Hedge can also be built onto the OpenArc platform. OpenArc also includes a programmable quote page (up to 540 symbols per page), custom quote page, options analysis, S&P data, montage, news, charting and an on-line symbol directory.

Micro Hedge Windows features include theoretical values, delta, gamma, theta, four valuation models, implied volatility, volatility distribution, dynamic skew, trading sheets, sensitivity analysis for all variables, matrix and plot of profit/loss and all derivatives over time and more. Micro Hedge analytics are accessible via DDE (dynamic data exchange) interface.

"I don't think of my setup as being glitzy and that's not the point anyway," says Gordon. "What I do is buy and sell all day, and while that may not sound glamorous either, I do require an information system that will help bring some order to the demands of my job."

Conversations with traders like Gordon make it appear that successful market manipulation can be pinned down, in part anyway, to having the right vendor "connections" -- maybe not a revolutionary concept, but one to bank on nevertheless.

specific information from U.S.-based warehouses.

When asked if further legislation over U.S.-based warehouses might cause the LME to remove its delivery points, King said the warehouses would remain in the United States because their locations have been established to benefit users of the market.

Asked why Sumitomo might have decreased its dealings in U.S. markets and increased its use of the LME several months after the exchange opened its U.S. warehouses, King replied the firm may have been looking for a more liquid market.

"I don't believe they moved, if they moved, to a less regulated market, but to a more appropriately structured market that is designed for industrial clients," he said.

Susan Phillips, member of the board of governors of the Federal Reserve, said more regulation may not be the answer to preventing market manipulation.

"Regulation, however, simply cannot substitute for sound management. Early episodes clearly demonstrate the very same problems can occur in regulated as well as unregulated firms and with exchange-traded contracts as well as with privately negotiated contracts," Phillips testified.

"Thus, a more appropriate response — indeed, for nonfinancial companies the only practical response — is to continue to promote policies that foster greater market discipline."

Phillips also confirmed losses from the Sumitomo affair appear to be confined and had not spread to other firms.

By Carla Cavaletti

IT'S LIQUIDITY, STUPID

CBOE ups S&P limits

Trading in S&P options at the Chicago Board Options Exchange (CBOE) became much more liberal in September 1996. No, Hunter S. Thompson didn't become a market maker. The Securities and Exchange Commission (SEC) approved treating synthetic stock instruments, such as collars, as one instrument for hedge purposes.

Hedge trimmer:

Contracts allowed before and after

	Before	After
S&P 500 position limit	45,000	100,000
S&P 500 exercise limit	45,000	100,000
Index hedge exemption	150,000	250,000
Firm facilitation exemption	100,000	400,000
Money manager exemption	250,000	350,000

The number of positions CBOE users can put on is growing. The maximum for some firms now can be as high as 750,000.

Source: CBOE

The SEC also approved increasing exercise and position limits as well as hedge exemptions at the CBOE. But treating synthetics as one instrument is the most significant approval, says Mary Bender, CBOE senior vice president of the regulatory services division.

"For the first time at the CBOE, we're able to take an equivalent position to an underlying basket and match it with the basket," Bender says. "This is a much more realistic treatment of the actual exposure of the position."

An example of a collar is a short call and a long put expiring together where the strike of the call is at least as much as the strike of the put. This type of instrument performs like a covered write position if the market rises and a long put if the market declines.

Before this change, a portfolio of securities could be matched up only with either the put or the call. Under the old exemption level of 150,000 for a single account (see "Hedge trimmer," page 16), a user could put on only 75,000 collars — 150,000 total puts and calls. The new treatment of synthetics and the increased hedge limits means users can put on 250,000 collars.

This change, as well as the increases in position and exercise limits and the larger hedge exemptions, are necessary if the CBOE is going to continue freeing its markets, according to the exchange.

"These increases are important to our exchange, making us more competitive with our counterparts in the futures markets, who have more flexible position limits," Bender says.

Not all market participants are happy with the changes. Howard Kotzen, executive vice president of securities, futures and options at ING Securities, Futures & Options Inc. in Chicago, says he agrees with increasing hedge exemptions and treating collars as one instrument but believes raising the position and exercise limits by 55,000 contracts gives traders too much leeway.

"Permitting people to put on larger sizes presents more risk to the clearing firm. You can't give traders a *carte blanche* as far as putting on size. Of course we have risk parameters, but those can't control what clients put on intraday," Kotzen says.

Now the overriding sentiment in the industry favors a delta-based position limit. In addition to lobbying harder for that, the CBOE will move to increase the limits in the S&P 100.

"We would always like to have less regulation and lower margins," says Richard Scarlata, director of research for Sutton Financial. "Recent changes are moving in that direction and will play a large part in attracting more institutional portfolio managers, especially the less-restrictive hedging requirements."

By James T. Holter

EXCHANGING FIRE

LIFFE and DTB vie for Euro traders

The question is not so much whether it will happen, but who

Field of dreams? - There are numerous packages available that have been designed to take the nightmares out of options trading

PETER TEMPLE, CERI JONES
Investors Chronicle, P. 62, 11 December 1998

Source: World Reporter (TM)

However experienced they might be in the equity market, investors keen on the idea of trading options find that the traded options market is rather different to the one they are used to.

Time is a critical variable in any option trade. An option has a limited lifespan, and its 'time value' erodes as the expiry date approaches, which means that the 'buy and hold' approach suitable for equity investments will not work in the options market. The options market requires disciplined trading, taking profits and cutting losses as they appear without letting emotion get in the way.

An understanding of how to read short term market movements and interpret the information that the market generates, is vitally important for successful trading. Most option professionals make extensive use of computer software to help them and a private trader who's new to the market should first become familiar with these techniques before they can hope to make money.

There are two main aspects to using software and market data effectively in the options market. One is becoming familiar with option pricing software; the second is being comfortable using technical analysis of price charts of the underlying securities to spot buying and selling opportunities that can be geared up through the options market.

Pricing model

Simple option pricing software helps the investor by defining - according to the information entered into it - a variety of different variables that can help a trader. The 'given' information is the price of an option, the underlying price, the strike price of the option and the length of time to expiry. From this information a simple pricing model can determine implied volatility and various measures of sensitivity. These can include, for example, the sensitivity of the price of the option to movements in the underlying price, or the speed at which the price of the option will decay over time.

Measuring volatility is important. If volatility is already high, then the chances are it will fall over time and work against a profitable outcome from the trade. A judgement therefore needs to be made, based on historical evidence, about whether or not the present level of volatility is high or low in terms of what has happened in the past.

Option pricing models are also very good at 'what if' scenarios. For instance, even the simplest model (look, for instance, at the various pricing calculators available at
www.numa.com) will allow you to enter
different values for the underlying security and its volatility, and

from that to calculate where the price of the option would be for given levels. This is a useful guide to working out a realistic view of the potential profitability of trades. Realism in this area is essential.

Charting packages

This is also where technical analysis packages come in. An option pricer needs to be used alongside a computerised charting package. This will graph the underlying share price and provide various technical indicators related to it, which will help to determine whether or not the shares are cheap or dear on a short term basis. One of the beauties of the options market is that it allows you to benefit from an overvalued share by buying a put option.

Many chart packages also allow the volatility of the share price to be calculated over time. Charting the course of the 90-day volatility in the share over a period of several years should provide a good guide to whether the present level of this parameter is low, high or about average.

Charts can also be used to identify trading ranges in shares either in terms of absolute price levels or in terms of movement to the upper or lower limits of currently establish trend channels. Many chart packages also allow trading volume parameters to be factored into the chart. Remember that price movements occurring on heavy volume carry more weight than those where volume is light.

Once again, like options, technical analysis is a large subject in itself and would-be option traders will find that investing in a good quality package and some books on the subject will pay-off in the long term. Some software suppliers also offer courses on technical analysis. Liffe publishes a guide to software suppliers producing packages suitable for use when trading options, details of which are available from 0171 623 0444 or from Liffe web site at www.liffe.com.

Why Market Maker Position Limits Should Be Delta-Based

Futures, Vol. 17, No. 9, PP. 42(2), August 1988
Ritchie, Joseph; Ginter, Gary
UMI Publication No.: 00415047
ISSN: 07462468
Subject Terms: Risk, Options markets, Limits, Investment advisors, Hedging
Classification Codes: 8130: Investment services; 3400: Investment analysis
UMI Journal Code: CMM

Abstract:

A key economic function of position limits in markets should be prevention of excessive amounts of risk among participants who are not prepared to manage that risk. A new method for establishing position limits for market makers in options is based on risk. It is proposed that risk be delta neutral and "gamma balanced." Delta is a measure of a position's current sensitivity to underlying price changes, and gamma is a measure of a position's propensity to change its delta or price exposure. By establishing different limits according to the market participants' economic functions, limits should reflect the distinct levels of participants' risk characteristics.

Market makers using the concepts of delta and gamma should focus on their total inventory risk, using a gamma-induced telescoping approach to reduce limits as expiration dates approach. Gamma-induced telescoping would require rolling positions forward into the out months where gamma risk is less.

NORTH-HOLLAND

International Review of Economics and Finance
12 (2003) 207–235

International Review of Economics & Finance

Calculation and comparison of delta-neutral and multiple-Greek dynamic hedge returns inclusive of market frictions

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Received 8 May 2001; received in revised form 20 May 2002; accepted 29 July 2002

Abstract

Evidence provided by traders in derivative-asset markets suggests that use of "delta-neutral" (DN) and "multiple-Greek" (MG) hedging strategies are a common and effective approach in achieving desired hedged investment goals. The principal objective of this research is to develop a model that calculates position returns for both DN and MG hedging effectiveness and incorporates Standard Portfolio Analysis of Risk (SPAN) margin requirements (MRs) as well as transaction costs (TCs). The results of this analysis show that a DN hedging approach activated by an increase in the implied volatility of the option produces a more effective hedge on a risk–return trade-off basis than the other hedging approaches examined.

JEL classification: G12; G13
Keywords: Delta-neutral; Multiple-Greek; Dynamic hedging; Margin requirements; Transaction costs

1. Introduction

Traders in derivative-asset markets employ a variety of dynamic strategies combining offsetting positions in options and/or futures to achieve desired "hedged" investment

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1059-0560/03/$ – see front matter © 2003 Elsevier Science Inc. All rights reserved.
doi:10.1016/S1059-0560(03)00002-9

objectives. Evidence provided by market practitioners suggests that use of so-called delta-neutral (DN) and multiple-Greek (MG) hedging strategies is a common and effective approach. In fact, use of these general hedging approaches are so commonplace that discussion and examples of their application appear in the publication of London International Financial Futures and Options Exchange (LIFFE), which provides them to any interested party.[1]

DN strategies are derived from the well-known option-pricing model of Black and Scholes (1973) or specifically, the Black (1976) model for valuing interest rate options on futures contracts. "Delta" is the term used to refer to the partial derivative ($\partial C/\partial F$ or $\partial P/\partial F$) for the change in the option (call or put) price with respect to a change in the underlying asset (futures) price from the Black option-pricing model. The general goal of a DN hedging approach is to make a combined option/futures portfolio immune to changes in the underlying asset. However, a DN-hedged portfolio is only immune to small changes in the underlying asset over the next short time period. To maintain delta neutrality the portfolio position must frequently be adjusted or *rebalanced.* The counterbalance to the potential effectiveness of frequent portfolio rebalancing is the possibly large amount of transaction costs (TCs) that the position incurs as it is dynamically adjusted.

In practice, traders are also concerned with changes in the hedged portfolio's value in response to changes in other variables that affect option prices. Some of these other important partial derivatives relate to changes in delta itself (gamma), changes in time-to-expiration (theta), and changes in the volatility of the underlying asset (vega). This research also examines an approach that combines all of these partial derivatives into an MG hedge ratio based on an approach suggested in a LIFFE (1995) publication.

The objectives of this research are as follows. First, a model is developed for use by practitioners that allows the calculation of dynamically hedged-option position returns that specifically accounts for the effects of margin requirement (MR) costs/returns as well as TCs within the framework suggested in a 1995 report prepared by LIFFE and Price Waterhouse (1995). This model is then validated using short-term interest rate derivatives market-price data to ensure that the model produces results, which intuition suggests should be expected. Second, tests are conducted to determine if the inclusion of margin and TCs produces nontrivial differences in mean returns or return volatility. Third, the effectiveness of DN hedges is compared to MG hedges. Finally, two risk-activated strategies drawn from practitioner comments are developed and tested against several automatic rebalancing approaches and a passive approach for mean-variance hedging effectiveness.

First, the empirical findings show that there is a significant difference between mean returns (107 of 162 comparisons) and return variances (75 of 162 cases) for naked options and DN-hedged option positions when market frictions are included vs. the comparative cases where these frictions are ignored. Second, DN hedges are surprisingly found to produce both significantly higher means and lower return variances in a large majority (76%) of cases compared to the more theoretically justified MG hedges. Finally, comparison of risk-

[1] *Short-Term Interest Rates: Futures and Options—An Introduction and Strategy Examples* (LIFFE, 1995).

activated hedges to automatically rebalanced hedges and a passive hedging strategy shows that a DN hedging approach based on an increase in the implied volatility of the option produces a more effective hedge on a risk–return trade-off basis than the other hedging approaches examined.

2. Review of the literature

An important assumption of the Black and Scholes (1973) option-pricing model is that capital markets are perfect, i.e., that there are no TCs. Another assumption is that asset trading takes place continuously so that the replicating portfolio used to determine the option's price is also continuously rebalanced. Boyle and Emanuel (1980) consider the distribution of hedged portfolio returns when rebalancing takes place on a discrete basis and find it to be particularly skewed and leptokurtic. They examine whether weekly rebalancing is optimal. Boyle and Emanuel conclude that hedging errors will be reasonably small if rebalancing is relatively frequent and can be ignored if the errors are uncorrelated with market return. Gilster and Lee (1984) modify the Black and Scholes pricing model to include the effects of TCs (as well as different borrowing and lending rates). Their empirical tests show that TCs of daily rebalancing were reasonably small and that the discrete rebalancing frequencies of the continuous-time option-pricing model do not seem to be a problem. Leland (1985) argues that the Black and Scholes arbitrage-based option-pricing model is invalidated by the inclusion of TCs. He develops an alternative replicating strategy that depends on the level of TCs and the rebalancing frequency. His approach is essentially an adjustment to the volatility used in the Black and Scholes formula. Boyle and Vorst (1992) rework Leland's analysis in a binomial framework. Their adjustment to the variance used in the model differs from Leland's model because although the binomial assumption provides the correct variance, it changes the expected absolute price change in any subinterval. Benet and Luft (1995) examine DN hedging of SPX stock index options and S&P 500 index futures in the presence of MRs and TCs. They examine 1-, 2-, and 4-week rebalancing intervals. They also use substantial changes in delta as a rebalancing trigger. Using the Howard and D'Antonio (1984) risk–return measure, they find that with inclusion of option premiums, TCs, and initial MRs, futures hedges are more effective than option hedges. Clewlow and Hodges (1997) build upon an earlier work by Hodges and Neuberger (1989) that examines writing and hedging a European call option in the presence of proportional TCs. Clewlow and Hodges employ a stochastic optimal control approach for DN hedging portfolios in the presence of TCs. The strategies developed focus on a band within which delta must be maintained. A fixed TC component leads to rebalancing to the inner band when an outer control limit is reached. Gallus (1999) notes that in a complete market model based on geometric Brownian motion a delta-hedging strategy may be used to price many types of exotic options. However, he shows that for specific contingent-claims digital options, if the underlying asset does not follow the assumed price process then DN hedging may actually increase the risk of the option writer.

A number of these studies analyze the Black and Scholes (1973) option-pricing model in the presence of TCs. However, none of these studies explicitly focus on incorporating the

daily changes in MRs arising from the Standard Portfolio Analysis of Risk (SPAN) margining system using market prices for short-term interest rate options and futures. Further, none of these studies develop a model that allows practitioners to determine position returns in a manner that reflects the accounting recommendations developed by LIFFE in conjunction with Price Waterhouse.

3. The model and "market imperfections" considered

3.1. Two risk-activated hedging strategies

To analyze DN and MG hedging effectiveness, the model developed here is based explicitly on the example cited on pages 67–69 in *Short-Term Interest Rates: Futures and Options—An Introduction and Strategy Examples* (LIFFE, 1995). In this example, the position is rebalanced on a daily basis using settlement prices. Through informal interviews, several traders have offered anecdotal evidence that suggests two important considerations when they trade. First, one trader who admitted that he had conducted analysis similar to this research concluded that 3-day (2-day) rebalancing is optimal for at-the-money calls (puts) when comparing automatic, daily rebalancing schemes. His comments suggest that daily rebalancing strategies may be employed by some traders. Second, the traders suggested that position risk is an important aspect of why they use dynamic, DN, or MG hedging techniques. They agreed with the author's suggestion that hedge rebalancing in response to increased risk might be a practical and potentially useful approach. Therefore, two dynamic, nonautomatically rebalanced trading strategies are devised that focus upon the risk characteristics of the overall hedged position.[2]

There are two objective measures of market volatility that a hedger in the LIFFE markets might utilize daily to determine if the hedge should be rebalanced. The first measure is whether the overall position's daily MR has increased according to the SPAN margining system because of its increased risk. As is noted in the proceeding discussion, the position's MR is recalculated every day based on the position's maximum loss (ML) under 16 different SPAN risk scenarios. If the maximum (potential) loss rises, then traders are required to post increased margin. Thus, an increase in the ML is an obvious risk indicator upon which to base a positional rebalancing. The first risk-activated strategy is then to rebalance the hedged position whenever the maximum loss (termed the *maximum loss* strategy) indicated by the SPAN system increases. The second measure is based on changes in the implied volatility of the option for which the futures contract is the underlying asset. Changes in the option's implied volatility may be taken as indication of increased risk, and therefore, also act as a rebalancing trigger. The second risk-activated hedging strategy, termed the *increased volatility* (IV) hedge, is then to rebalance the hedged position whenever the implied volatility of the option increases.

[2] These approaches are conceptually similar to that analyzed in Benet and Luft (1995).

An additional point that must be noted is that the hedging strategies analyzed here are based on using end-of-day (settlement) price data. For example, Black and Scholes (1972) assume that the hedged portfolio in their empirical tests is rebalanced on a daily basis. Other researchers including Boyle and Emanuel (1980) and more recently, Clewlow and Hodges (1997) focus on (minimal) daily hedge rebalancing. In fact, the minimum, automatic rebalancing frequency considered by Benet and Luft (1995) and Leland (1985) is 1 week.

Clearly, large institutional investors could be expected to base their position rebalancing on intraday price changes and adjust them accordingly. However, potential intraday rebalancing would necessarily increase the TCs of any strategy analyzed and quite probably to a significant extent. Evidence from practitioners suggests that some DN traders do in fact use end-of-day position adjustment.[3] This fact should not be taken as indicating that intraday price changes are unimportant. Rather, it may suggest that typical practice for some hedgers is to focus on end-of-day rebalancing. In any event, in this study, no strategy will enjoy a comparative advantage because they are all based on end-of-day data.

To develop the final model utilized here, the following sections describe, respectively, the hypotheses analyzed, the SPAN system for determining initial MRs, the TCs, and data sets employed. This discussion is then followed by development of the equations and overall return model incorporating all MRs/TCs.

3.2. Hypotheses analyzed

In this analysis, several issues regarding hedging effectiveness are considered. To more clearly focus on each of these issues, the hypotheses examined here are enumerated specifically as follows. In a practical application of DN or MG hedging, a trader will incur TCs and cash inflows/outflows related to initial and variation margins, which will be dependent on the frequency of portfolio rebalancing. These costs and cash flows may seriously affect the returns earned on the hedged portfolio. Thus,

Hypothesis 1: A comparison of hedged returns that include these transaction and margin costs/returns to the returns earned on the portfolio without considering these costs will show that mean returns and return variances differ significantly.

A DN hedging strategy rebalances the portfolio based on the option's sensitivity to changes in the underlying futures contract. Theoretically, an MG hedging approach should be superior as it also takes into account changes due to decreasing time-to-expiration, implied volatility, and changes in delta itself. Hypothesis 2 then follows:

Hypothesis 2: The MG hedging strategy is expected to produce significantly higher mean returns and/or significantly lower return variances in comparison to a DN hedging strategy.

[3] Additionally, London SPAN "risk arrays are calculated centrally each day using the closing market prices to illustrate how much the portfolio would gain or lose using the closing market prices and initial margin parameters" (LIFFE, 1996, p. 38).

There is a trade-off between return-variability reduction benefits through increased frequency of rebalancing and the higher TCs of this frequent rebalancing. These higher costs will necessarily lower the portfolio's return. The determination of a superior hedging approach should clearly consider the risk–return trade-off. The hedging benefit per unit of risk (termed *HBS*) developed by Howard and D'Antonio (1987) is utilized here for this purpose. As the HBS measure includes both risk and return in its calculation, it is an empirical question whether increased returns or decreased volatility will dominate the generation of superior HBS measures. Automatic rebalancing schemes may tend to increase TCs unnecessarily in comparison to risk-triggered hedging approaches and both will certainly generate greater TCs than a passive hedging strategy. However, increased rebalancing frequency is expected to reduce position variance. Hypothesis 3 may be stated as:

Hypothesis 3: Hedges based on increased-risk rebalancing are expected to provide a superior risk–return trade-off compared to automatic hedge rebalancing strategies.

Where appropriate, findings in the Results section will be referenced to the particular hypothesis that is being tested.

3.3. Determining initial MRs via the SPAN system and variation margin

3.3.1. The London Clearing House

The primary purpose of the London Clearing House (LCH) is to act, in relation to its members, as central counterparty for contracts traded on London's futures and options exchanges. To limit and cover the potential loss, LCH collects margin on all open positions and recalculates members' margin liabilities on a daily basis. The two major types of margin are initial and variation margin.

3.3.1.1. Initial margin requirements.

Span parameters and scanning range. LCH uses London SPAN to calculate initial MRs for LIFFE.[4] London SPAN builds on and adapts the SPAN framework developed by the Chicago Mercantile Exchange (Chicago Board Options Exchange, 1995). In conjunction with the exchange, LCH sets initial margin parameters for each contract. The two main parameters are a futures price move, known either as the *initial margin rate* or the *futures scanning range*, and an *implied volatility shift*. These are set with reference to historical data on prices and volatilities and other factors such as known price-sensitive events. The parameters are kept under continuous review by LCH but do not change on a daily basis. London SPAN parameters as of 25 February 1997 are used in the analysis throughout for consistent calculation of returns.

London SPAN divides contracts into groups of futures and futures options relating to a single underlying asset (e.g., Short Sterling futures and options on Short Sterling futures). These groups are referred to as "portfolios." At the first stage of calculation, London SPAN simulates how the value of a portfolio would react to the changing market conditions defined

[4] This section draws upon *Understanding London SPAN* published by the London Clearing House (1994).

Scenario	Futures Price Changes	Implied Volatility Changes
1	Futures price down 3/3 range	Volatility up
2	Futures price down 3/3 range	Volatility down
3	Futures price down 2/3 range	Volatility up
4	Futures price down 2/3 range	Volatility down
5	Futures price down 1/3 range	Volatility up
6	Futures price down 1/3 range	Volatility down
7	Futures price unchanged	Volatility up
8	Futures price unchanged	Volatility down
9	Futures price up 1/3 range	Volatility up
10	Futures price up 1/3 range	Volatility down
11	Futures price up 2/3 range	Volatility up
12	Futures price up 2/3 range	Volatility down
13	Futures price up 3/3 range	Volatility up
14	Futures price up 3/3 range	Volatility down
15	Futures up extreme move	Volatility unchanged
16	Futures down extreme move	Volatility unchanged

Fig. 1.

in the initial margin parameters. This is done by forming a series of market scenarios and evaluating the portfolio under each set of conditions.

London SPAN uses 16 market scenarios in conjunction with the scanning range and volatility shift parameter to determine the potential profits/losses for each contract (futures month or option series) by comparing the current (market) price with the calculated contract price under each scenario. Futures prices are determined directly through the various scenarios. Option prices are calculated using the Black (1976) model based on the various futures prices and volatilities in the 16 scenarios. The 16 profits/losses for each contract then form a *risk array*. Fig. 1 above details the 16 market scenarios used in the calculation of London SPAN to form the risk array.

Risk arrays and scanning risk. Risk arrays are calculated each day using the closing futures and options prices. By valuing each net position (future or option) with the appropriate array and then combining arrays, London SPAN determines which scenario generates the ML for the portfolio, which may consist of either naked or combined positions. This ML is then referred to as the *scanning risk*. Scanning risk is the principal input into the calculation of the initial MR. Under SPAN, the initial MR changes each day as rates move and as the relative values of the portfolio components change. Changes in the initial MR need to be funded as long as positions remain open.[5]

3.3.1.2. Variation margins. Each day, open futures and options contracts are "marked-to-market" and daily profits or losses are paid through variation margin. For LIFFE financial options, payment of premium on initiation is not mandatory. If an option gradually becomes

[5] *Futures and Options—Accounting and Administration* (LIFFE & Price Waterhouse, 1995, p. 7).

Short Sterling	£ 3.00
Euromark	DM 8.00
Euroswiss	Sf 6.50

Fig. 2.

worthless, then the premium is effectively paid over time via the variation margin.[6] Having determined the profit or loss on a marked-to-market basis, the whole of the profit or loss should be recognized immediately. This recognizes the fact that each day a trader effectively decides either to keep a position open or to close it.[7] Changes in variation margin, therefore, need to be explicitly accounted for in the daily portfolio-return calculations.

3.4. Transaction costs

A sample of brokerage firms in Ireland and the United Kingdom was contacted in an effort to determine typical institutional TCs. Several firms responded and the round-trip costs used in this analysis are essentially an average of those provided. The derivative contracts examined here are denominated in their own domestic currency, so the TCs in the three relevant currencies are given above in Fig. 2.[8]

3.5. Data sets analyzed

The daily closing (settle) prices, as well as other data, e.g., implied volatilities for the futures options and contracts examined here are provided by LIFFE. The short-term interest rate markets analyzed are the 3-month Short Sterling, Euromark, and Euroswiss contracts. In each market, the period considered essentially dates from the inception of futures option trading. For Short Sterling, analysis begins with the March 1989 contract. Euromark and Euroswiss analysis begin with the March 1991 and September 1993 contracts, respectively. Analysis for all contracts ends with the March 1998 contract inclusive.

For each contract maturity, three calls and three puts are chosen for analysis. The contracts chosen are those with the three strike prices closest to the average futures (underlying asset) price over the period of analysis.[9] For each contract, a period of 130 trading days is analyzed, which typically commences about 280 (calendar) days from the option's expiration. This

[6] Ibid.

[7] Ibid. (p. 21).

[8] These transaction costs are somewhat lower than those employed by Benet and Luft (1995) who report that interviewed market participants put round-trip transaction costs at \$8–10.

[9] Options that are close to being "at-the-money" are utilized in this analysis to avoid the possibility that it might be optimal to exercise any of the puts early. Hull (1997, pp. 162–66) shows that it will never be optimal to exercise a call (on a non-dividend-paying stock) early and only optimal for a similar put if it is sufficiently deeply in-the-money.

normally corresponds to the advent of trading in the contract and this approach insures that final portfolio reversal occurs well before the expiration month. The objective of using this investment period is to minimize the compression in option deltas (to their value at expiration) as expiration approaches. In addition, to minimize any potential beginning- or end-of-the-week effects, all positions are initiated on a Wednesday. Once the returns for a given contract have been calculated, they are aggregated into a composite file for each option. Return analysis described in the Results section is then based on these composite return files. This approach conforms with the LIFFE guidelines stated as: "A suitable report to management evaluating hedge performance should contain details of:. . .the hedge efficiency being achieved, the trend over time being a more significant measure of performance than the result of any individual open hedging transaction."[10]

3.6. Portfolio return model

3.6.1. Theoretical option-pricing model

The Black (1976) pricing model is the most widely used and recognized option-pricing model for LIFFE options. The models for pricing short-term interest rate options[11] are as follows:

$$C = [(100 - X) \times N(-d_2)] - [(100 - F) \times N(-d_1)], \text{ and} \tag{1}$$

$$P = [(100 - F) \times N(d_1)] - [(100 - X) \times N(d_2)], \tag{2}$$

where

$$d_1 = \left[\frac{\ln\left(\frac{R_f}{R_x}\right) + \frac{1}{2} S^2 T}{S\sqrt{T}} \right],$$

$$d_2 = d_1 - (S\sqrt{T}),$$

$$N(-d_1) = 1 - N(d_1) \text{ and}$$

$$N(-d_2) = 1 - N(d_2),$$

with C as the call premium, P as the put premium, F as the futures price, X as the strike price, R_f as the rate implied by futures price (i.e., 100 − futures), R_x as the rate implied by strike price (i.e., 100 − strike), S as the volatility of 3-month rates measured by annual standard deviation, T as the time to expiration in years, and $N(d)$ as the cumulative probability distribution function for a standardized normal variable.

[10] *Futures and Options—Accounting and Administration* (LIFFE & Price Waterhouse, 1995, p. 41).

[11] *Short-Term Interest Rates: Futures and Options* (LIFFE, 1995, p. 64). See also Stoll and Whaley (1993, p. 372) for similar valuation formulas.

Actual LIFFE market prices are used in all portfolio-return calculations. However, as noted above, the Black (1976) model prices are used by the SPAN system to determine initial MRs. In this model, the underlying futures prices are assumed log-normally distributed. The partial derivatives[12] of this version of the Black model with respect to F(Delta) are as follows:

$$\delta_C(\text{Delta}) = \partial C/\partial F = N(-d_1). \tag{3}$$

$$\delta_P(\text{Delta}) = \partial P/\partial F = -N(d_1). \tag{4}$$

Delta is the expected change in the option's value for a small change in the futures price and serves as the hedge ratio in the DN hedging strategy. Delta sensitivity for a long call (long put) position is positive (negative), meaning that the call position benefits from an increase in the futures price whereas the put position loses.

3.6.2. Calculation of the MG hedge ratio

Option values are also sensitive to changes in other variables in the model. Theta is the expected change in the option's value as the time-to-expiration decreases. The sensitivity of both calls and puts to a decrease in time-to-expiration is negative. The calculation of theta is given in Eq. (5) and is the same for both calls and puts (as is also true of vega and gamma that follow).

$$\text{Theta}_C(\partial C/\partial T) = \text{Theta}_P(\partial P/\partial T) = [R_X \times S \times Z(d_1)]/(2\sqrt{T}), \tag{5}$$

where

$$Z(d_1) = \partial N(d_1)/\partial d_1 = \left[\frac{e^{-(d_1)^2/2}}{\sqrt{2\pi}}\right].$$

Vega (sometimes called *kappa*) represents the expected change in the option's value for a 1% change in the option's volatility. There is a direct relationship between option volatility and option value. Eq. (6) shows the calculation of vega utilized in this research.

$$\text{Vega}_C(\partial C/\partial S) = \text{Vega}_P(\partial P/\partial S) = R_F \times \sqrt{T} \times Z(d_1). \tag{6}$$

Gamma is defined as the expected change in the option delta for an incremental change in the value of the underlying asset. A long call or put position will have positive gamma sensitivity, meaning that delta increases if the underlying futures price increases.

$$\text{Gamma}_C(\partial\Delta_C/\partial F) = \text{Gamma}_P(\partial\Delta_P/\partial F) = Z(d_1)/(R_F \times S \times \sqrt{T}). \tag{7}$$

The approach suggested by LIFFE for aggregating these four sensitivities into a combined hedge ratio is surprisingly simple. "The overall sensitivity of a portfolio can be obtained by

[12] Ibid. LIFFE also provides calculated deltas as part of the daily settlement price information it supplies to interested parties. Note that the deltas in Eqs. (3) and (4) differ from traditional "stock option" deltas, but are consistent with the short-term interest rate option valuation formulas given in Eqs. (1) and (2) above, as well as those in Stoll and Whaley (1993, p. 372).

adding up the delta, gamma, theta, and vega of each individual option position on the same underlying (asset)" (LIFFE, 1995, p. 66). Thus, the multiple-Greek hedge ratios (MGHR) for hedging calls and puts are calculated as in Eqs. (8) and (9) below.

$$\mathrm{MGHR}_C = \mathrm{Delta}_C + \mathrm{Gamma}_C - \mathrm{Theta}_C + \mathrm{Vega}_C. \tag{8}$$

$$\mathrm{MGHR}_P = \mathrm{Delta}_P + \mathrm{Gamma}_P - \mathrm{Theta}_P + \mathrm{Vega}_P. \tag{9}$$

In the models developed below, the discussion is couched in terms of DN hedges, but it applies equally to MG hedges. The only difference in the model (and the analysis that is conducted) is that the MG hedge ratio is substituted for the DN hedge ratio.

3.6.3. Initial and variation margins

As discussed above, SPAN initial margins are calculated on a daily basis for naked or combination positions. In the analysis here, return comparisons are made for naked option positions vs. futures-hedged portfolio positions. The formulas presented below are therefore developed for option-only positions and for hedged positions. Assume that time i represents any day between initiation at time 0 and final position closure after n days. Time k is some date greater than or equal to day 2, and is less than or equal to day n. To represent cumulative returns of day 0 through day i, k is used, where the overall investment is n days. Reversal i refers to the daily reversal from a position opened on day $i-t$ and reversed on day i, whereas t represents the number of days elapsing since the most recently preceding trading day. It should be noted that the detailed formulas below generally relate to a long call position hedged using short futures and a daily DN rebalancing frequency. The initial SPAN MR for a call-only position (SPAN call-only margin, or SCOM) is given in Eq. (10) and the SPAN initial hedge margin (SIHM) is given in Eq. (11).

$$\mathrm{SCOM}_i = \mathrm{Max\ Loss}_i(\mathrm{SPAN\ Call\ Loss}_i). \tag{10}$$

$$\begin{aligned}\mathrm{SIHM}(x)_i &= \mathrm{Max\ Loss}_i(\mathrm{SPAN\ Call\ Loss}_i + \mathrm{SPAN\ DN\ Future\ Loss}_x)\\ &= \mathrm{Max\ Loss}_i(\mathrm{SCL}_i + \mathrm{SFL}_i),\end{aligned} \tag{11}$$

where $\mathrm{SIHM}(x)_i$ is the SPAN initial hedge margin (recalculated daily) for reversal i and rebalancing frequency x.

Note that the scenario generating the ML SPAN call-only margin in Eq. (10) will not necessarily be the same scenario as that generating span call loss in Eq. (11). The SPAN scenario where the ML occurs could easily differ where the call-only position is held compared to where the call position is combined with offsetting futures into a portfolio. Six different automatic rebalancing frequencies are examined. DN H1A refers to daily-adjusted hedges where the returns include all TCs and margin returns/costs. DN H2A, H3A, H4A, and H5A refer to DN hedges with a 2-day, 3-day, weekly, and biweekly rebalancing frequency, respectively. DN H6A refers to a DN strategy, which when initiated is DN but may be termed passive as the futures position is not subsequently adjusted. The ML strategy is then labeled DN H7A, and DN H8A refers to the IV approach.

The call-only daily variation margin (CDVM) is given as follows:

$$\mathrm{CDVM}_i(\text{Long Calls}) = (-C_{i-t} + C_i)\mathrm{CP} \times \mathrm{TV} \times 100, \tag{12}$$

where C_i is the settle call futures option price on day i, CP is the call (or put) position (assumed to equal 100 contracts), and TV is the tick value.

Multiplication of the daily positional profit/loss by 100 is used to convert tick value to an actual (£Stg./DM/Sf) value. Cumulative variation margin then represents net profit/loss to date. Call-only cumulative variation margin (CCVM) from initiation at $i=0$, to the reversal at k, is then given as:

$$\mathrm{CCVM}_{i,k} = \sum_{i=1}^{k} \mathrm{CDVM}_i = \gamma_{i,k}. \tag{13}$$

The next necessary distinction regards the initial (base or non-delta-adjusted) futures position vs. the delta-adjusted futures component. The initial futures daily variation margin (IFDVM) is given in Eq. (14). Then the initial futures cumulative variation margin (IFCVM) at reversal k is given in Eq. (15). Since the call or put is assumed to be held long, the futures hedge for a call (put) is assumed to be a short (long) position and this is reflected in the IFP term.

$$\mathrm{IFDVM}_i = (-F_{i-t} + F_i)\mathrm{IFP} \times \mathrm{TV} \times 100, \tag{14}$$

$$\mathrm{IFCVM}_{i,k} = \sum_{i=1}^{k} \mathrm{IFDVM}_i = \phi_{i,k}, \tag{15}$$

where F_i is the settle short-term interest rate futures on day i and IFP is the initial futures position (initial delta$(-\mathrm{CP})$).

The daily delta adjustment (DA_i) for reversal i and then the cumulative delta adjustment (CDA) as of reversal k are given in turn.

$$\mathrm{DA}_i = (\delta_{i-t} - \delta_i)(-\mathrm{CP}). \tag{16}$$

$$\mathrm{CDA}_{i,k} = \sum_{i=1}^{k} [(\delta_{i-t} - \delta_i)(-\mathrm{CP})] = \varphi_{i,k}. \tag{17}$$

The call position term appears in Eqs. (16) and (17) to convert the decimal values of the daily delta adjustment to a contract basis. The ith delta-adjusted daily variation margin (DADVM) as of reversal k is then shown in Eq. (18).

$$\mathrm{DADVM}_{i,k} = \varphi_{i,k}[(-F_{i-t} + F_i)\mathrm{TV} \times 100]. \tag{18}$$

The delta-adjusted cumulative variation margin (DACVM) as of reversal k then follows in Eq. (19).

$$\mathrm{DACVM}_{i,k} = \sum_{i=1}^{k} \mathrm{DADVM}_i = \eta_{i,k}. \tag{19}$$

3.6.4. Return on initial and variation margins

The returns/costs on initial and variation margins are the next input to overall calculation of the positions' returns in the model. The approach used here to account for these returns or costs is based on guidelines suggested by LIFFE. In general, the initial margin is treated as a use of cash and thereby generates an opportunity cost of funds. Capital gains/losses from futures or options positions as represented by changes in the variation margins are assumed to be allocated to the cash account.[13] The question arising then in determining the corresponding costs/returns for these cash flows is "What cash interest rate to use?" The LIFFE suggestion is that "a notional rate must be used...that should be the rate earned on the rest of the cash part of the portfolio."[14] The notional margin rate (r_m) adopted here from the LIFFE Recommendations (1992, p. 32) is an annual rate of 3%.

The equations used for calculating margin costs/returns are explicitly formulated to account for the considerations enumerated above, namely daily revision of the initial SPAN MR and changes in the variation margin. Thus, the return for each daily reversal is calculated and then summed up to reflect the return calculation as of reversal k. For the naked option position, the cumulative option SPAN initial margin cost (COIMC) is shown in Eq. (20).

$$\mathrm{COIMC}_{i,k} = \sum_{i=1}^{k}[\mathrm{SCOM}_i(r_\mathrm{m}(i-(i-t))/365)] = \kappa_{i,k}. \tag{20}$$

Similarly, the cumulative hedge SPAN initial margin cost (CHIMC) for rebalancing frequency x as of reversal k is given as:

$$\mathrm{CHIMC}_{i,k} = \sum_{i=1}^{k}[\mathrm{SIHM}(x)_i(r_\mathrm{m}(i-(i-t))/365)] = \lambda_{k,n}. \tag{21}$$

Given the above considerations, the same calculation approach leads to the formulas for the cumulative option variation margin return (COVMR) in Eq. (22) and the cumulative hedge variation margin return (CHVMR) in Eq. (23).

$$\mathrm{COVMR}_{i,k} = \sum_{i=1}^{k}[(\gamma_i)(r_\mathrm{m}(i-(i-t))/365)] = \theta_{i,k}. \tag{22}$$

$$\mathrm{CHVMR}_{i,k} = \sum_{i=1}^{k}[(\gamma_i+\phi_i+\eta_i)(r_\mathrm{m}(i-(i-t))/365)] = v_{i,k}. \tag{23}$$

3.6.5. Transaction costs

The estimated TCs employed in the model are given above on a round-trip basis. This cost approach simplifies the calculation of the returns, which are analyzed on the basis of daily position reversal. To deal with the different positions analyzed, TCs are subdivided into three

[13] *The Reporting and Performance Measurement of Financial Futures and Options in Investment Portfolios* (LIFFE Recommendations, 1992, pp. 29, 36–41).

[14] Ibid. (p. 34).

categories. These components are the following: initial option position TCs (OTC), base futures position TCs (BFTC), and delta-adjusted futures TCs (DAFTC). Thus, total hedge transaction costs (THTC) as of reversal k are given as:

$$\mathrm{THTC}_{i,k} = \mathrm{OTC}_{i,k} + \mathrm{BFTC}_{i,k} + \mathrm{DAFTC}_{i,k}. \tag{24}$$

3.6.6. Return calculation model

In the finance literature, it is well recognized that return calculations involving futures and options are somewhat difficult due to the fractional margin required to support the larger "market-value" of derivative positions. LIFFE Recommendations (1992, p. 31) stipulate that "it is not possible to measure performance on a 'margin payment' basis, i.e., by using the capital gain on the futures position against either that of the equity or the cash components of the portfolio. This would lead ultimately to nonsensical figures for the return on parts of the portfolio.... Therefore, an **adjustment must be made to an associated economic exposure basis, equivalent to that made in the reporting process**" (emphasis in the original). To account for this, the market-value economic exposure is directly reflected here for naked options or on a "net-basis" in the hedged portfolio returns.

Tests of Hypothesis 1 for the significance of including TCs and margin returns, require comparison of the relevant returns with, and without, inclusion of those costs and/or returns. The efficacy of DN and MG hedging strategies is tested by calculating returns for naked-option positions as well as for the corresponding futures-hedged portfolio positions. The four return models below are developed to deal with these considerations. The long call and put returns without TCs/MRs as of reversal k are given in Eqs. (25) and (26), respectively.

$$R(C)_{\mathrm{NTC},k} = \left[\frac{(-C_0 + C_k)}{C_0}\right]\left[\frac{365}{k}\right]. \tag{25}$$

$$R(P)_{\mathrm{NTC},k} = \left[\frac{(-P_0 + P_k)}{P_0}\right]\left[\frac{365}{k}\right], \tag{26}$$

where P_k is the settle put futures option price on day k.

The return calculation for the call-only position inclusive of all TCs and MRs is given in Eq. (27).

$$R(C)_{\mathrm{ATC},k} = \left[\frac{(\gamma_{i,k} + \theta_{i,k} - \kappa_{i,k}) + (-\mathrm{SCOM}_0 + \mathrm{SCOM}_k) - \mathrm{OTC}_k}{((C_0 \times \mathrm{CP} \times \mathrm{TV} \times 100) + \mathrm{SCOM}_k) + \gamma_{i,k}}\right]\left[\frac{365}{k}\right]. \tag{27}$$

Two points of clarification should be mentioned concerning the formulation given in Eq. (27). First, the difference between the SPAN MR at initiation and at reversal is included in the numerator to account for the daily recalculation as described earlier. Second, the SPAN initial

MR as of reversal at day k is included in the denominator because it represents the amount of funds tied up in initial margin as of that date. Further, SCOM_k is considered part of the investment since the cost of funds tied up in initial margin as represented in the $\kappa_{i,k}$ term are in the numerator.

The return on a delta-adjusted hedge where TCs/margin returns are ignored (NTC) is given in Eq. (28). The absolute value of the long call position offset by the short futures is used in the denominator to reflect the net economic exposure basis of the offsetting positions of the hedged portfolio.

$$R(H)_{\mathrm{NTC},k} = \left[\frac{\eta_{i,k}}{(|(C_0 \times \mathrm{CP}) + (F_0 \times \mathrm{IFP})|\mathrm{TV} \times 100)}\right]\left[\frac{365}{k}\right]. \tag{28}$$

Finally, the return on the delta-adjusted hedge considering all TCs and margin returns (ATC) is given in Eq. (29) as follows.

$$R(H)_{\mathrm{ATC},k} = \left[\frac{(\gamma_{i,k} + \phi_{i,k} + \eta_{i,k} + \nu_{i,k} - \lambda_{i,k}) + (-\mathrm{SIHM}_0 + \mathrm{SIHM}_k) - \mathrm{THTC}_k}{((|(C_0 \times \mathrm{CP}) + (F_0 \times \mathrm{IFP})|\mathrm{TV} \times 100) + \mathrm{SIHM}_k) + \eta_{i,k}}\right]\left[\frac{365}{k}\right]. \tag{29}$$

It may be noted that the preceding formulations all utilize the initial option and/or futures prices as the base for the return calculations. Clearly, this approach yields return calculations that are effectively decreased in magnitude by the annualization factor as the reversal date gets farther from the initiation date. The calculation approach is derived from the method suggested in LIFFE Recommendations (1992, p. 49). The approach obviously compresses the returns that could be calculated alternatively on the basis of using the daily return calculated as $[(P_{i-t} - P_i)/P_{i-t}]$ where P_i equals the price on day i. However, since all returns here are calculated on a similar basis, they are comparable and do not reflect any particular bias arising from the calculation approach regarding the hypotheses examined.

4. Results

Discussion of the analysis of returns on short-term interest rate contract hedging generally proceeds in order of the hypotheses proposed earlier. Hypothesis 1 states that it is expected that there will be a significant difference between position returns and return variability where a comparison is made of returns that include TCs/MRs (termed *inclusive returns*) to returns excluding (termed *exclusive returns*) them. Evidence regarding this hypothesis is given for the at-the-money calls and puts in Table 1. This table provides annualized returns and standard deviations for naked option positions as well as the DN- and MG-hedged portfolios for each of the eight strategies. An indication of whether the

Table 1
Risk–return measures for unhedged options vs. DN and MG futures-hedged portfolios

Option/hedge	DN hedges		MG hedges		Option/hedge	DN hedges		MG hedges	
	Rtn (%)	S.D. (%)	Rtn (%)	S.D. (%)		Rtn (%)	S.D. (%)	Rtn (%)	S.D. (%)
Market: Short Sterling									
Call 2A	−38.856**	1268.535**	−38.856**	1268.535**	Put 2A	69.890	1760.818**	69.890	1760.818**
Call 2B	114.901	1160.517	114.901	1160.517	Put 2B	69.997	736.201	69.997	736.201
H1A	−0.435**	2.744	−0.606	3.445	H1A	−0.204*	3.381	7.608**	47.291**
H1B	−0.287	2.775	−0.508	3.418	H1B	−0.050	3.451	16.142	81.642
H2A	−0.348**	2.932	−0.537	3.423	H2A	−0.244*	3.327	7.496**	47.372**
H2B	−0.205	2.983	−0.445	3.400	H2B	−0.098	3.393	16.019	81.637
H3A	−0.305*	2.899	−0.513	3.373	H3A	−0.261*	3.323	7.119**	46.591**
H3B	−0.168	2.938	−0.425	3.351	H3B	−0.118	3.387	15.340	79.431
H4A	−0.317*	3.172*	−0.525	3.392	H4A	−0.239*	3.307	7.733**	47.636**
H4B	−0.177	3.263	−0.439	3.370	H4B	−0.101	3.369	16.449	82.038
H5A	−0.224	3.418**	−0.462	3.348	H5A	−0.240	3.201	7.342**	46.903**
H5B	−0.089	3.549	−0.387	3.333	H5B	−0.117	3.267	15.958	81.113
H6A	−0.033	4.530**	−0.334	3.250	H6A	−0.314*	2.273	6.206**	44.357**
H6B	0.134	4.933	−0.264	3.240	H6B	−0.214	2.291	13.276	67.918
H7A	−0.388*	2.829	−0.575	3.489	H7A	−0.194*	3.404	7.201**	48.194**
H7B	−0.254	2.860	−0.486	3.465	H7B	−0.052	3.475	16.058	83.006
H8A	−0.363*	2.914	−0.543	3.396	H8A	−0.216	3.336	7.837**	47.486**
H8B	−0.243	2.953	−0.467	3.375	H8B	−0.091	3.398	16.259	81.201
Market: Euromark									
Call 2A	−46.620**	952.406**	−46.620**	952.406**	Put 2A	−8.744**	587.822**	−8.744**	587.822**
Call 2B	209.327	1168.265	209.327	1168.327	Put 2B	−76.190	511.195	−76.190	511.195
H1A	−0.430**	2.051	−0.917*	2.964	H1A	−0.524**	1.722	−3.923	43.20**
H1B	−0.196	2.023	−0.777	2.893	H1B	−0.374	1.678	−3.721	46.88
H2A	−0.367**	2.167	−0.873*	2.851	H2A	−0.517**	1.706	−3.534	42.06**
H2B	−0.147	2.155	−0.744	2.792	H2B	−0.376	1.663	−3.337	46.04
H3A	−0.450**	2.003	−0.932	3.019	H3A	−0.511**	1.708	−3.144	41.30**
H3B	−0.240	1.957	−0.807	2.956	H3B	−0.374	1.663	−2.954	45.52
H4A	−0.345**	2.191	−0.851	2.809	H4A	−0.534**	1.686	−3.861	42.61**
H4B	−0.139	2.176	−0.731	2.759	H4B	−0.400	1.642	−3.558	46.38
H5A	−0.323**	2.237	−0.830	2.776	H5A	−0.530**	1.662	−3.385	41.38**

H5B	−0.130	2.215	−0.724	2.740	H5B	−0.406	1.619	−3.111	45.64
H6A	0.196*	4.524**	−0.430*	2.106	H6A	−0.454**	1.504*	−2.997	40.04**
H6B	0.447	4.971	−0.338	2.101	H6B	−0.342	1.453	−2.304	44.64
H7A	−0.531**	1.959*	−0.981	3.078	H7A	−0.500**	1.665	−3.761	42.80**
H7B	−0.327	1.894	−0.859	3.013	H7B	−0.366	1.620	−3.338	46.61
H8A	−0.371**	2.067	−0.859	2.907	H8A	−0.501**	1.708	−4.033	42.91**
H8B	−0.190	2.007	−0.755	2.864	H8B	−0.381	1.665	−3.804	46.86
Market: Euroswiss									
Call 2A	72.634**	3128.722**	72.634**	3128.722**	Put 2A	−123.201**	900.875**	−123.201**	900.875**
Call 2B	631.667	1520.845	631.667	1520.845	Put 2B	−178.718	723.383	−178.718	723.383
H1A	0.042*	3.586	−1.622	3.052	H1A	−0.110	2.880	−5.415	56.313**
H1B	0.254	3.681	−1.495	2.952	H1B	−0.001	2.793	−5.359	61.403
H2A	0.167*	3.655	−1.558	2.992	H2A	−0.123	2.842	−4.956	56.082**
H2B	0.364	3.746	−1.442	2.891	H2B	−0.022	2.759	−4.914	61.242
H3A	0.164	3.616	−1.548	2.943	H3A	−0.118	2.836	−5.747	57.714**
H3B	0.354	3.707	−1.438	2.843	H3B	−0.020	2.753	−5.690	62.676
H4A	0.194	3.678	−1.599	2.887	H4A	−0.105	2.824	−6.637	57.781**
H4B	0.378	3.768	−1.425	2.786	H4B	−0.010	2.741	−6.592	62.495
H5A	0.350	3.877	−1.411	2.786	H5A	−0.126	2.797	−6.164	57.517**
H5B	0.521	3.972	−1.325	2.692	H5B	−0.039	2.714	−6.057	62.409
H6A	1.088	4.738	−0.815	2.465**	H6A	−0.178	2.644	−5.681	56.573**
H6B	1.283	4.870	−0.742	2.352	H6B	−0.100	2.556	−5.136	62.064
H7A	0.013	3.630	−1.642	3.004	H7A	−0.127	2.794	−5.998	57.519**
H7B	0.201	3.727	−1.532	2.906	H7B	−0.031	2.709	−5.747	62.350
H8A	0.184	3.730	−1.507	2.910	H8A	−0.076	2.833	−5.457	56.271**
H8B	0.344	3.818	−1.419	2.814	H8B	0.009	2.749	−5.407	61.469

Return A includes TCs and margin returns whereas Return B excludes them. Call or Put 2 refers to the at-the-money option. H(x) refers to either the DN or MG hedge with rebalancing frequency x. H1 is the daily adjusted hedge, H2, H3, H4, and H5 are the second-day, third-day, weekly, and biweekly adjusted hedges, respectively. H6 is the passive hedge strategy. H7 (H8) is the ML (IV) hedging strategy. Rtn is the annualized option or hedged position return. S.D. is the standard deviation of returns. t indicates whether the paired t test for a significant difference in mean return A vs. B is significant. F indicates whether the folded F statistic testing for a significant difference in variances is significant.

* Significance at the 5% level.

** Significance at the 1% level.

Market/Option	Delta-Neutral Hedges Significant t-Tests	Delta-Neutral Hedges Significant F-Tests	Multiple-Greek Hedges Significant t-Tests	Multiple-Greek Hedges Significant F-Tests
Short Sterling Calls	23/27	15/27	3/27	5/27
Short Sterling Puts	19/27	11/27	15/27	27/27
Euromark Calls	27/27	20/27	17/27	8/27
Euromark Puts	27/27	16/27	5/27	27/27
Euroswiss Calls	8/27	10/27	3/27	4/27
Euroswiss Puts	3/27	3/27	3/27	19/27
Total	**107/162**	**75/162**	**46/162**	**90/162**

Fig. 3. Summary comparison of naked options, DN, and MG hedge returns inclusive of margin and TCs vs. exclusive returns.

parametric statistics for significant differences in means (paired t tests) and variability (F tests) is also shown in Table 1. These statistics have been estimated using the SAS PROC TTEST (SAS Institute, 1985b).[15] The forms of the paired t and the "folded" F tests are given in Eqs. (30) and (31) below.

$$\text{Paired } t \text{ statistic} = \left[\frac{(\mu_1 - \mu_2)}{\sqrt{\left(\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right)}}\right], \text{ and} \tag{30}$$

$$\text{Folded } F \text{ test} = \left[\frac{\text{Larger of } (\sigma_1^2, \sigma_2^2)}{\text{Smaller of } (\sigma_1^2, \sigma_2^2)}\right], \tag{31}$$

where μ_i is the sample mean of return series i and σ_i^2 is the sample variance of return series i.

The in-the-money and out-of-the-money results are not provided in the table[16] in the interest of brevity. However, in the interest of completeness, those results are included in the summary statistics that are detailed above in Fig. 3. The number of returns included for each of the six options in a given market are as follows: Short Sterling (4773), Euromark (3741), and Euroswiss (2451). As is shown in Table 1, and indeed is true for all 18 options, there is a significant difference between inclusive and exclusive returns for all naked options in terms of mean returns and variances (standard deviations reported) as evidenced by paired t and F tests. Interestingly, comparison of mean inclusive to exclusive returns shows that the sign of

[15] Additionally, SAS PROC UNIVARIATE (SAS Institute, 1985a) is used to test the (difference between compared) returns for normality. The Kolmogorov D statistic testing for normality rejects the hypothesis that any of the return distributions are normal. Given this, a signed rank test is used to test the hypothesis that the population mean is zero. Results of this nonparametric test for the various comparisons described in Hypotheses 1–3 show that the t tests reported here understate the level of significant differences in mean returns.

[16] These and other additional results are available from the author.

the naked option return changes from negative (for inclusive returns) to positive (for exclusive returns) in 6 of 18 cases.

Table 1 shows that there are consistent, significant differences in both t and F tests for MG hedges in Short Sterling puts. Consistent differences in mean returns are significant for DN hedges in both Euromark calls and puts. MG comparisons for F values are consistently significant for both Euromark and Euroswiss puts. Summary results for all 18 options and hedges combined as well as based on each market are provided in Fig. 3. In this figure, the results are considered significant if the k value equals 5% or less. Viewing the overall results based on the combined figures it is clear that there is a significant difference in means between inclusive and exclusive returns in a large majority (66%) of cases for DN hedges although there is none for MG hedges. Conversely, a majority of MG hedges (55.6%) yield significantly lower variances in the presence of margin and TCs while only 46.3% of these comparisons are significantly different for DN hedges. When the inclusive vs. exclusive comparison is made by market, it is clear that the highest number of significant differences is evidenced by the Short Sterling and Euromark markets for DN hedges (and to a lesser extent the MG hedges). The Euroswiss market evidences the fewest number of significant differences, which is perhaps largely due to the relatively lower number of returns in its analysis. In sum, these overall results suggest that the effect of including TCs and MRs in the return calculations produce nontrivial differences as compared to returns where these costs/returns are ignored. Thus, in all results evaluated henceforth, the analysis cites inclusive returns rather than exclusive returns.

Validation of the model proposed to account for all option and futures returns, as well as the margin and TCs, is an additional aspect of this research. It is intuitively obvious that a DN (MG) hedging approach is expected to be successful at reducing portfolio variability as compared to naked option positions. When hedging effectiveness is measured in terms of variance reduction both the DN and MG approaches are indeed effective based on the F test. For all six options in each of the three markets, all eight of the DN hedging frequencies (144 comparisons) yield highly significant F tests. Similarly, uniform variance reduction for the MG hedges is also observed for all comparisons. Given the uniformity of the F statistics, these results are not reproduced here although it is of interest to report the extent to which option-only variability is eliminated through hedging on average. Accordingly, the average S.D. of returns for all naked options is calculated to be 1360%, whereas the average S.D. for all DN hedges is 3%. Based on these averages, the average reduction in return S.D. achieved through DN hedging is found to be 99.78%. Thus, it might be said that, on average, 99.78% of naked option return variability is eliminated through DN hedging. Similar risk-reduction results are found for CG hedges. A potentially more interesting question is whether apart from risk reduction the DN or CG hedges actually improve returns. Table 2 details the results of the t tests for significant differences in naked-option means vs. hedged returns. The daily-adjusted returns are provided as these t statistics are largely representative of returns for all hedge strategies. Focusing on daily-adjusted hedges may provide a conservative portrayal of hedge returns as this strategy would tend to have the highest rebalancing TCs. As the top panel of Table 2 shows, 8 of the 18 DN-hedged means are significantly higher (or less negative) than the unhedged-option means. Conversely, in three cases, the unhedged-option

Table 2
Comparison of unhedged-option return to daily-adjusted DN and combined Greek hedge return using paired t test for difference in means

Market	Option	μ_O vs. μ_H	t statistic	Option	μ_O vs. μ_H	t statistic
DN hedges						
Short Sterling	Call 1	(−)<(−)	−0.0175	Put 1	(+)>(−)	0.9058
	Call 2	(−)<(−)	−2.0905*	Put 2	(+)>(−)	2.7470**
	Call 3	(−)<(−)	−2.5523**	Put 3	(+)>(−)	4.3515**
Euromark	Call 1	(+)>(−)	0.0731	Put 1	(−)<(+)	−4.2661**
	Call 2	(−)<(−)	−2.9635**	Put 2	(−)<(−)	−0.8551
	Call 3	(−)<(−)	−3.7674**	Put 3	(+)>(−)	1.3069
Euroswiss	Call 1	(+)>(−)	2.0657*	Put 1	(−)<(+)	−8.6825**
	Call 2	(+)>(+)	1.1456	Put 2	(−)<(−)	−6.7575**
	Call 3	(+)>(+)	0.6574	Put 3	(−)<(+)	−3.4974**
MG hedges						
Short Sterling	Call 1	(−)<(−)	−0.0085	Put 1	(+)>(+)	1.4772
	Call 2	(−)<(−)	−2.0812*	Put 2	(+)>(+)	2.4467**
	Call 3	(−)<(−)	−2.3845**	Put 3	(+)>(+)	4.3189**
Euromark	Call 1	(+)>(−)	0.0939	Put 1	(−)<(+)	−4.5253**
	Call 2	(−)<(−)	−2.9322**	Put 2	(−)<(−)	−0.5002
	Call 3	(−)<(−)	−3.7383**	Put 3	(+)>(+)	1.1638
Euroswiss	Call 1	(+)>(−)	2.0956*	Put 1	(−)<(−)	−8.6025**
	Call 2	(+)>(−)	1.1719	Put 2	(−)<(−)	−5.5937**
	Call 3	(+)>(−)	0.7121	Put 3	(−)<(−)	−3.4486**

Call 2 and Put 2 are the at-the-money options. Call 1 and Put 3 are the in-the-money options. Call 3 and Put 1 are the out-of-the-money options. μ_O vs. μ_H shows a comparison of the mean of the unhedged option to the mean of the (daily-adjusted) DN or MG hedge return. The (+) or (−) signs indicate whether the mean is greater than or less than zero. The inequality sign shows which of the two means is greater (or less negative). t Statistic shows the parametric test statistic testing for a significant difference in sample means.

* Significance at the 5% level.

** Significance at the 1% level.

mean is positive, the hedge mean is negative, and the t statistics are significant. The remaining seven comparisons do not generate significant t statistics. The bottom panel of Table 2 depicts results for the MG hedges that essentially mirror the DN results. Reference to the hedged means in Table 1 generally shows these means are quite close to zero (although this is not true for MG-hedged puts). So, the overall conclusion that may be reached regarding hedging returns is that in 44% of the cases examined here, the DN hedges transformed significant option losses into portfolio returns near zero, even after accounting for all of the costs of undertaking the hedges. In the seven cases where the mean returns compared are not significantly different, at a minimum, the hedges minimized portfolio losses.

Hypothesis 2 asserts that MG hedges should provide greater risk reduction, higher hedged means, or both, in comparison to DN hedges. The results of the parametric analysis of this hypothesis are shown in Table 3 for the at-the-money options.

Table 3
Comparison of DN to MG hedge returns

Comparison	At-the-money call			At-the-money put		
	t statistic	*F* statistic	Lower S.D.	*t* statistic	*F* statistic	Lower S.D.
Short Sterling						
DN H1A vs. MG H1A	2.683**	1.58**	DN	− 11.384**	195.66**	DN
DN H2A vs. MG H2A	2.900**	1.36**	DN	− 11.260**	202.69**	DN
DN H3A vs. MG H3A	3.228**	1.35**	DN	− 10.914**	196.63**	DN
DN H4A vs. MG H4A	3.097**	1.14**	DN	− 11.534**	207.52**	DN
DN H5A vs. MG H5A	3.425**	1.04	MG	− 11.142**	214.66**	DN
DN H6A vs. MG H6A	3.724**	1.94**	MG	− 10.141**	380.73**	DN
DN H7A vs. MG H7A	2.871**	1.52**	DN	− 10.574**	200.40**	DN
DN H8A vs. MG H8A	2.774**	1.36**	DN	− 11.688**	202.59**	DN
Euromark						
DN H1A vs. MG H1A	8.276**	2.09**	DN	4.807**	629.4**	DN
DN H2A vs. MG H2A	8.639**	1.73**	DN	4.384**	607.5**	DN
DN H3A vs. MG H3A	8.148**	2.27**	DN	3.896**	584.7**	DN
DN H4A vs. MG H4A	8.694**	1.64**	DN	4.772**	638.5**	DN
DN H5A vs. MG H5A	8.693**	1.54**	DN	4.218**	620.4**	DN
DN H6A vs. MG H6A	7.669**	4.62**	MG	3.882**	709.0**	DN
DN H7A vs. MG H7A	7.550**	2.47**	DN	4.657**	661.2**	DN
DN H8A vs. MG H8A	8.374**	1.98**	DN	5.031**	630.9**	DN
Euroswiss						
DN H1A vs. MG H1A	17.497**	1.38**	MG	4.658**	382.4**	DN
DN H2A vs. MG H2A	18.080**	1.49**	MG	4.260**	389.5**	DN
DN H3A vs. MG H3A	18.178**	1.51**	MG	4.822**	414.1**	DN
DN H4A vs. MG H4A	18.258**	1.62**	MG	5.590**	418.6**	DN
DN H5A vs. MG H5A	18.259**	1.94**	MG	5.191**	423.0**	DN
DN H6A vs. MG H6A	17.640**	3.70**	MG	4.811**	457.8**	DN
DN H7A vs. MG H7A	17.393**	1.46**	MG	5.048**	423.7**	DN
DN H8A vs. MG H8A	17.706**	1.64**	MG	4.728**	394.4**	DN

DN (MG) H1A is the daily-adjusted delta-neutral (multiple-Greek) hedge including all TCs/MRs. H2A, H3A, H4A, and H5A are the second-day, third-day, weekly, and biweekly adjusted hedges. H6A is the passive hedge strategy. H7A is the ML hedging strategy and H8A is the IV hedging strategy. *t* Statistic compares the DN hedge mean return to the corresponding MG hedge mean. Similarly, *F* statistic tests for a significant difference in return variances. Lower S.D. indicates whether the DN or MG hedge produces the lower standard deviation.

** Significance at the 1% level.

The form of the numerator in the *t* statistic is the DN mean minus the MG mean. Thus, a positive *t* statistic means that the DN mean is higher (or less negative) than the MG mean. All of the 48 *t* statistics shown in Table 3 are highly significant, although out of 144 comparisons (including the 12 options not shown), only 119 are significant. The results in Table 3 indicate that DN hedges have higher means than their MG counterparts except for Short Sterling puts. Summing all results, DN-hedged returns exceed the MG returns in 110 cases, of which 101 exhibit significant *t* statistics.

All of the F test statistics shown in Table 3 are highly significant except one case. Indeed, 136 comparisons of the total 144 turn out to be significant. The MG hedges consistently produce lower variances for only Euroswiss calls. The DN hedges lead to uniformly lower variances for all the puts shown in Table 3 and for most of the Short Sterling and Euromark calls. Overall, DN-hedged variances are lower in 109 cases and of these 108 are significant (including all 72 put comparisons). Based on the analysis for these three markets, the DN hedges prove to yield higher and less variable returns in a large majority of cases. Given the overall dominance of the DN hedges the remaining analysis and discussion focuses on those results.

One aspect of this analysis that may be driving these comparative results is the simple approach utilized to aggregate the partial derivatives into the MG hedge ratio suggested in the LIFFE publication. Textbook examples as in Hull (1997, Chap. 14) or Stoll and Whaley (1993, Chap. 12) suggest that for each Greek effect that is being hedged, a different option is needed to implement the hedge. Such a strategy employing numerous options would certainly lead to an increase in TCs and reduce hedge returns. Further, it would not work in the LIFFE strategy analyzed here as the base position is considered the option and the hedge asset is the futures contract.

To examine Hypothesis 3, the means and variances of the two risk-triggered hedging strategies are compared to their counterparts from the other six hedging approaches. Table 4 depicts the parametric results for the at-the-money options. The form of the numerator in the t test is the other hedge (OH) mean vs. the ML hedge mean. The t statistics for calls in all three markets are almost uniformly positive and are markedly significant for Euromark calls. Biweekly and passive other hedges have significantly higher means than ML hedges in the Short Sterling and Euroswiss markets for calls. ML hedged-put returns fare better against the other hedges for Short Sterling and the Euromark although the t tests are typically not significant. Out of all 126 comparisons, 27 are significant. ML hedge returns are higher in 40 cases, but only two of these are significant. Table 4 indicates that the ML hedging approach seems to perform better at reducing risk than generating higher returns. ML hedges provide significant variance reduction for Short Sterling and Euromark calls in most cases. In fact, the example where ML hedges offer consistently less variance reduction is for Short Sterling puts. The F statistics are significant in 57 of 126 comparisons. ML hedges yield (significantly) lower hedge variances in (39) 86 cases.

Table 5 provides the results of the parametric tests comparing IV hedges to the other hedges for the at-the-money options. The IV hedges generate mean hedge returns that are not generally significantly different from the other hedges except in comparison to the passive hedges. For calls, the other hedges typically have superior mean returns, whereas the opposite is true for puts. Of all 126 comparisons, only 17 have significant t statistics. The IV-hedged return exceeds its OH counterpart in 82 cases, with five cases being significant. Table 5 also shows that the contest for producing lower variances is a rather back-and-forth affair. The IV hedge for calls appears to be most effective at reducing risk in comparison to biweekly and passive hedges. In contrast, passive hedge returns are significantly lower than IV hedges for puts in all three markets. Overall, 44 (of 126) F statistics are significant. IV hedges generate lower variances in 49 cases and 23 cases are significant.

Table 4
Comparison of DN to ML hedge returns

Comparison	At-the-money call			At-the-money put		
	t statistic	*F* statistic	Lower S.D.	*t* statistic	*F* statistic	Lower S.D.
Short Sterling						
DN H1A vs. DN H7A	−0.831	1.06*	OH	−0.153	1.01	OH
DN H2A vs. DN H7A	0.681	1.07**	ML	−0.736	1.05	OH
DN H3A vs. DN H7A	1.412	1.05	ML	−0.974	1.05	OH
DN H4A vs. DN H7A	1.152	1.26**	ML	−0.655	1.06*	OH
DN H5A vs. DN H7A	2.547**	1.46**	ML	−0.686	1.13**	OH
DN H6A vs. DN H7A	4.590**	2.56**	ML	−2.026*	2.24**	OH
DN H8A vs. DN H7A	0.425	1.06*	ML	−0.328	1.04	OH
Euromark						
DN H1A vs. DN H7A	2.184*	1.10**	ML	−0.631	1.07*	ML
DN H2A vs. DN H7A	3.438**	1.22**	ML	−0.441	1.05	ML
DN H3A vs. DN H7A	1.774	1.05	ML	−0.284	1.05	ML
DN H4A vs. DN H7A	3.877**	1.25**	ML	−0.890	1.03	ML
DN H5A vs. DN H7A	4.274**	1.30**	ML	−0.780	1.00	OH
DN H6A vs. DN H7A	9.017**	5.33**	ML	1.231	1.23**	OH
DN H8A vs. DN H7A	3.441**	1.11**	ML	−0.031	1.05	ML
Euroswiss						
DN H1A vs. DN H7A	0.284	1.02	OH	0.210	1.06	ML
DN H2A vs. DN H7A	1.473	1.01	ML	0.041	1.03	ML
DN H3A vs. DN H7A	1.456	1.01	OH	0.104	1.03	ML
DN H4A vs. DN H7A	1.734	1.03	ML	0.268	1.02	ML
DN H5A vs. DN H7A	3.135**	1.14**	ML	0.006	1.00	ML
DN H6A vs. DN H7A	8.916**	1.70**	ML	−0.659	1.12**	OH
DN H8A vs. DN H7A	1.629	1.06	ML	0.628	1.03	ML

DN H1A is the daily-adjusted delta-neutral hedge including all TCs/MRs. H2A, H3A, H4A, and H5A are the second-day, third-day, weekly, and biweekly adjusted hedges. H6A is the passive hedge strategy. H7A is the ML hedging strategy and H8A is the IV hedging strategy. *t* Statistic compares other DN hedge mean returns to the ML hedge mean. Similarly, *F* statistic tests for a significant difference in return variances. Lower S.D. indicates whether the OH or ML hedge produces the lower standard deviation.

* Significance at the 5% level.

** Significance at the 1% level.

A risk–return measure is developed by Howard and D'Antonio (1987), which they term the HBS. This measure is used to provide further evidence on Hypothesis 3. The form of their HBS measure is given in Eq. (27) below for the relevant comparison, which is an unhedged option to a DN-hedged position.

$$\mathrm{HBS} = [(r_{\mathrm{m}} + ((\mu_{\mathrm{H}} - r_{\mathrm{m}})/\sigma_{\mathrm{H}})\sigma_{\mathrm{U}} - \mu_{\mathrm{U}})/\sigma_{\mathrm{U}}], \qquad (32)$$

where $\mu_{\mathrm{U(H)}}$ is the unhedged (hedged) portfolio mean return and $\sigma_{\mathrm{U(H)}}$ is the unhedged (hedged) portfolio standard deviation.

Table 5
Comparison of DN to IV hedge returns

Comparison	At-the-money call			At-the-money put		
	t statistic	*F* statistic	Lower S.D.	*t* statistic	*F* statistic	Lower S.D.
Short Sterling						
DN H1A vs. DN H8A	−1.249	1.13**	OH	0.175	1.03	IV
DN H2A vs. DN H8A	0.254	1.01	IV	−0.412	1.01	OH
DN H3A vs. DN H8A	0.971	1.01	OH	−0.652	1.01	OH
DN H4A vs. DN H8A	0.736	1.18**	IV	−0.330	1.02	OH
DN H5A vs. DN H8A	2.131*	1.38**	IV	−0.355	1.09**	OH
DN H6A vs. DN H8A	4.230**	2.42**	IV	−1.667	2.15**	OH
DN H7A vs. DN H8A	−0.425	1.06*	OH	0.328	1.04	IV
Euromark						
DN H1A vs. DN H8A	−1.238	1.02	OH	−0.593	1.02	IV
DN H2A vs. DN H8A	0.082	1.10**	IV	−0.405	1.00	OH
DN H3A vs. DN H8A	−1.677	1.06	OH	−0.250	1.00	OH
DN H4A vs. DN H8A	0.530	1.12**	IV	−0.848	1.03	OH
DN H5A vs. DN H8A	0.956	1.17**	IV	−0.739	1.06	OH
DN H6A vs. DN H8A	6.968**	4.79**	IV	1.245	1.29**	OH
DN H7A vs. DN H8A	−3.441**	1.11**	OH	0.031	1.05	OH
Euroswiss						
DN H1A vs. DN H8A	−1.359	1.08*	OH	−0.411	1.03	IV
DN H2A vs. DN H8A	−0.171	1.04	OH	−0.583	1.01	IV
DN H3A vs. DN H8A	−0.196	1.06	OH	−0.521	1.00	IV
DN H4A vs. DN H8A	0.092	1.03	OH	−0.358	1.01	OH
DN H5A vs. DN H8A	1.518	1.08*	IV	−0.622	1.03	OH
DN H6A vs. DN H8A	7.418**	1.61**	IV	−1.299	1.15**	OH
DN H7A vs. DN H8A	−1.629	1.06	OH	−0.628	1.03	OH

DN H1A is the daily-adjusted delta-neutral hedge including all TCs/MRs. H2A, H3A, H4A, and H5A are the second-day, third-day, weekly, and biweekly adjusted hedges. H6A is the passive hedge strategy. H7A is the ML hedging strategy and H8A is the IV hedging strategy. *t* Statistic compares the other DN hedge mean returns to the IV hedge mean. Similarly, *F* statistic tests for a significant difference in return variances. Lower S.D. indicates whether the OH or IV hedge produces the lower standard deviation.

* Significance at the 5% level.

** Significance at the 1% level.

As may be readily determined, the higher the excess standardized hedged return in relation to the unhedged return and standard deviation, the higher (more positive) will be the HBS measure.

The HBS measures comparing the effectiveness of DN hedges at reducing naked-option risk are provided in Table 6. To compare the various hedging approaches to one another, for a given option, the HBS measure from each approach is ranked against the other HBS measures. These relative rankings provide information as to which hedging approach is most effective at providing the best risk–return trade-off for a particular option in each

Table 6
Comparison of ranked HBS measures for unhedged-option position vs. eight DN hedge returns including all TCs and margin returns

Option	HBS1	R1	HBS2	R2	HBS3	R3	HBS4	R4	HBS5	R5	HBS6	R6	HBS7	R7	HBS8	R8
SSC1	−1.3762	8	−1.2969	5	−1.2924	4	−1.2238	3	−1.1318	2	−0.8540	1	−1.3278	7	−1.3054	6
SSC2	−1.2188	8	−1.1087	5	−1.1071	4	−1.0126	3	−0.9103	2	−0.6366	1	−1.1648	7	−1.1209	6
SSC3	−0.9581	8	−0.8490	4	−0.8498	5	−0.7281	3	−0.6514	2	−0.4204	1	−0.8966	7	−0.8735	6
SSP1	−0.8565	3	−0.8815	4	−0.8872	6	−0.8869	5	−0.9132	7	−1.2785	8	−0.8471	1	−0.8532	2
SSP2	−0.9857	2	−1.0130	4	−1.0193	6	−1.0174	5	−1.0501	7	−1.4956	8	−0.9760	1	−1.0020	3
SSP3	−1.0628	2	−1.0873	4	−1.0981	6	−1.0933	5	−1.1310	7	−1.6429	8	−1.0615	1	−1.0741	3
EMC1	−1.2283	7	−1.1826	5	−1.1943	6	−1.1696	3	−1.0802	2	−0.7328	1	−1.2374	8	−1.1718	4
EMC2	−0.8469	8	−0.7976	5	−0.8065	6	−0.7852	4	−0.7059	2	−0.4258	1	−0.8452	7	−0.7771	3
EMC3	−0.4282	8	−0.3894	5	−0.3897	6	−0.3859	4	−0.3375	2	−0.1504	1	−0.4248	7	−0.3769	3
EMP1	−0.7735	1	−0.7935	5	−0.7912	4	−0.7903	3	−0.8100	6	−0.9369	8	−0.8219	7	−0.7803	2
EMP2	−0.9397	1	−0.9590	3	−0.9594	5	−0.9594	4	−0.9778	6	−1.0618	8	−0.9788	7	−0.9456	2
EMP3	−1.3971	1	−1.4214	4	−1.4188	3	−1.4234	5	−1.4419	6	−1.5868	8	−1.4444	7	−1.4096	2
ESC1	−1.8856	5	−1.7656	4	−1.9762	7	−1.6507	2	−1.6532	3	−0.7205	1	−2.0272	8	−1.8859	6
ESC2	−1.6199	6	−1.5013	4	−1.6698	7	−1.4741	3	−1.4331	2	−0.5677	1	−1.7503	8	−1.5788	5
ESC3	−1.1142	5	−1.0659	2	−1.2224	8	−1.1186	6	−1.0983	4	−0.4204	1	−1.1551	7	−1.0853	3
ESP1	−1.7158	1	−1.7307	4	−1.7278	3	−1.7674	5	−1.7931	6	−1.9646	8	−1.8287	7	−1.7210	2
ESP2	−2.0265	1	−2.0410	4	−2.0356	3	−2.0757	5	−2.1043	7	−2.2774	8	−2.0824	6	−2.0291	2
ESP3	−2.4852	1	−2.4969	3	−2.4999	4	−2.5337	5	−2.5647	7	−2.7817	8	−2.5428	6	−2.4894	2
Mean	−1.2733	4.22	−1.2434	4.11	−1.2748	5.17	−1.2276	4.06	−1.2104	4.44	−1.1086	4.50	−1.3007	6.06	−1.2489	3.44
S.D.	0.5111	3.04	0.5115	0.83	0.5289	1.50	0.5231	1.11	0.5457	2.25	0.7206	3.60	0.5459	2.39	0.5228	1.62

HBS(x) is the Howard and D'Antonio (1987) risk–return measure that compares the unhedged option's return and standard deviation to those of the DN hedge with the rebalancing frequency denoted as x. R(x) is the relative ranking of the HBS measure for a given option hedge. SSCz (SSPz), EMCz (EMPz), and ESCz (ESPz) is the abbreviation for Short Sterling calls (puts), Euromark calls (puts), and Euroswiss calls (puts), respectively. When $z=1$ it refers to the in-the-money call and the out-of-the-money put. $z=2$ is the at-the-money call and put. $z=3$ refers to the out-of-the-money call and the in-the-money put. S.D. is the standard deviation.

market. The HBS measures for the hedges are uniformly negative. This measure is based on the excess standardized hedge return so this is not too surprising. The notional risk-free return (r_{m}) used throughout the analysis is 3%, which is clearly larger than the mean return earned on many of the hedges as is shown in Table 1.

Summary statistics regarding the ranks from Table 6 show that the IV hedge approach ranks as the best HBS-based strategy with an average rank of 3.4. The weekly rebalancing frequency generates an average rank of 4.06. Based on its mean rank, the ML hedging approach comes in last place. Closer examination of Table 6 shows that the passive hedge ranks in first place for all nine calls, but ranks last for all puts. Conversely, daily rebalancing is a poor approach for hedging calls but works very well for puts. The IV hedging strategy is quite effective for puts and is modestly successful for calls.

Wilcoxon signed-rank testing is conducted for both HBS measures and rankings. The results show that IV, 2-day (DN2), and weekly (DN4) rebalanced hedges offer a significantly better risk–return trade-off vs. the 3-day (DN3) and the ML hedge (DN7) strategies based on either ranks or HBS measures. Additionally, the biweekly rebalancing approach (DN5) has significantly lower rankings and less negative HBS measures than DN7.

5. Summary and conclusions

This study examines both DN and MG hedging approaches that are popular with traders in LIFFE short-term interest rate derivative markets. To make the analysis as useful and realistic as possible, "real-world" market imperfections are explicitly incorporated into the hedging model that is developed and then tested empirically. Specifically, the portfolio-return model accounts for the impact of TCs and the costs/returns associated with initial and variation MRs. This study explicitly focuses on incorporating the daily recalculation of MRs arising from the SPAN margining system using market prices for short-term interest rate options and futures. Further, the developed model allows practitioners to determine position returns in a manner that reflects the accounting recommendations developed by LIFFE in conjunction with Price Waterhouse.

There are three principal conclusions derived from the empirical analysis. First, a comparison of returns inclusive of TCs/MRs to where they are excluded evidences statistically significant differences using parametric (and nonparametric) tests in a large number of the comparisons examined. Thus, these market imperfections may be considered nontrivial. The model is validated by analysis showing that hedged portfolio returns (variances) are significantly higher (lower) when portfolio rebalancing occurs less (more) frequently as intuition suggests.

Second, in practice, traders are concerned with position sensitivities other than just delta. An approach described in a LIFFE publication for aggregating delta, vega, theta, and gamma is employed to calculate an MG hedge ratio. All hedging effectiveness analysis is conducted for both DN and MG hedge ratios. In this analysis, DN hedges are surprisingly found to produce both significantly higher means and lower return variances in a large majority of cases compared to the more theoretically justified MG hedges.

Finally, two risk-activated hedge approaches are compared to automatically rebalanced hedges and a passive hedging strategy on the basis of mean-variance hedging effectiveness. The results of this analysis show that a DN hedging approach activated by an increase in the implied volatility of the option produces a more effective hedge on a risk–return trade-off basis than the other hedging approaches examined. Conversely, the risk-activated hedging strategy triggered by an increase in the daily ML calculated by the SPAN margining system does not prove to be an effective hedging approach. Another unexpected result is that 2-day and weekly rebalanced hedges prove significantly better than 3-day rebalanced hedges.

The primary implication of this study for future researchers is that any analysis based on the simplifying assumption of no transaction or margin costs may be seriously flawed or at a minimum may yield misleading results. Several results suggest implications for practitioners. Hedgers who are considering the use of a DN hedging approach should be impressed with the unambiguous and significant risk-reduction characteristics of all the hedging approaches analyzed. Further, the predominance of the passive hedging approach in all three call markets suggests that less frequent position rebalancing may be quite effective for calls and will certainly reduce TCs. By contrast, daily rebalancing is a commendable approach for hedging puts. Hedgers may also wish to consider increases in the implied volatility of the underlying asset as a signal for position rebalancing given its overall effectiveness here for both calls and puts. Finally, hedgers who are concerned about incorporating effects due to gamma, vega, or theta should perhaps look beyond a simple aggregation of these sensitivities into one hedge ratio.

A simplification employed here is the Black and Scholes (1973) assumption of log-normally distributed returns of the underlying asset. The appeal of this assumption is that in the model there is only one unobserved parameter, the variance of returns. Other return distributions like the jump diffusion model exists, which more accurately account for the widely recognized possibility of "fat-tails" and they may be more theoretically desirable. However, the jump diffusion model requires estimation of three unobserved parameters (Simmons, 1997, p. 26), which increases the complexity of its use. Additionally, instead of the Black (1976) European option-pricing model, a variant like the Barone-Adesi and Whaley (1987) model for an efficient analytical approximation of American option values could be used to calculate the hedging deltas and other Greeks.

One final limitation of this research is the fact that only three LIFFE short-term interest rate option and futures markets are analyzed. An interesting extension would be to analyze DN and MG hedging strategies in additional markets and different exchanges.

Acknowledgements

Thanks are due to the London International Financial Futures and Options Exchange (LIFFE) for providing price data and relevant publications and to the London Clearing House (LCH) for providing information regarding the SPAN margining system. Practical comments

regarding the implementation of the model received from Ronan O'Connor are much appreciated. Thanks for valuable comments are due to two anonymous referees, the editor, Carl R. Chen, as well as David Colwell, Stephen Figlewski, Paul Gronewoller, Martin Lally, Russell Poskitt, and Lawrence Rose. Comments from seminar participants at Massey University-Palmerston North, the 2nd New Zealand Finance Colloquium and the 11th Annual Australasian Banking and Finance Conference are also appreciated. The contribution of Kester McWeeny and my 1997 Derivative Securities class at University College Dublin in validating the original model must also be acknowledged. Finally, thanks to James Roberts for his valuable SAS programming expertise. Any remaining errors are the responsibility of the author.

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A Novel Approach to Transactions-Based Currency Exposure Management

Ira G. Kawaller, *Vice President-Director, Chicago Mercantile Exchange, New York*

In the traditional futures hedging situation, gains or losses due to price movement of the underlying exposure are offset by losses or gains in the futures hedge. The futures hedge effectively serves to lock in a price. This note demonstrates that, by buying options, where the consolidated delta of the option position equals the alternative futures hedge ratio, the hedger may be able to generate results superior to those of the traditional futures hedge in both rising and falling price environments.

Consider a U.S. investor who decides to buy British securities. At the time of the trade, the price of the securities is fixed in pounds sterling; but given traditional settlement and clearing conventions, the exchange of dollars for sterling would likely be deferred for some limited time (e.g., several days), exposing the trade to the risk of sterling strengthening in the interim.

Clearly, one way of dealing with this exposure is to initiate a long British pound futures position and maintain it until the trade date of the spot currency transaction. In this case, the hedge would offset either adverse or beneficial changes in the dollar-pound exchange rate, thereby making the hedger indifferent to exchange rate variability. Using options in a **delta-equivalent fashion** (i.e., where the consolidated delta of the option hedge equals the number of futures contracts required for the traditional futures hedge rate) provides an alternative that may be worthy of consideration. This **option hedge** alternative to the traditional **futures hedge** strategy offers the prospect of covering the risk and at the same time permitting incrementally superior results.

To illustrate, suppose the hedger in the above example substituted two **at-the-money** calls for each long futures contract required. As at-the-money calls have deltas equal to 0.5 or 50%, this option position should generate a result approximately equal to that of the futures hedge for small moves of the underlying pound futures price. Over more substantial exchange rate moves, however, the option strategy should provide a more attractive outcome. For example, if sterling strengthened (i.e., exchange rates moved adversely for the underlying exposure), the calls would become **in-the-money**, and each call's delta would increase above 0.50. As a consequence, the option hedge would start to generate greater profits than the futures hedge, allowing the option hedger actually to benefit from the strengthening of the British pound.

In the opposite market environment, with weakening sterling, the option strategy would again be more attractive. This time, the call would be moving **out-of-the-money**, and the deltas would be declining. The option hedge losses would thus be smaller than the futures hedge losses. Moreover, losses from the option hedge would fall short of the savings from being able to purchase the British securities at a more attractive exchange rate (i.e., with the weaker sterling), allowing for some overall benefit from a weakening British pound. Importantly, this strategy does not require an adjustment to the hedge ratio or the number of option contracts employed. That is, once the option hedge is initiated, it is maintained without adjustment exactly as long as one would otherwise maintain the traditional futures hedge.

As compelling as the advantages of this delta-equivalent option strategy may appear, however, the approach may not be unconditionally preferable. The qualification has to do with erosion of time value. Accepted nomenclature divides an option's price or premium into intrinsic value and time value. The intrinsic value is simply the difference between the option's strike price and the price of the underlying instrument, when this difference is beneficial (zero otherwise). The remaining portion of the option price, then, is time value. Time value reflects sensitivity to the market's perception of the degree of price variance expected over the remaining life of the option.

A basic characteristic of option prices is that, at the option's expiration, the premium should settle to a price equal to the option's intrinsic value; in other words,

Table I Option Hedge Outcomes

	Stronger BP (+2.0%)	*Weaker BP (−2.0%)*	*Stable BP (0.0%)*
Home Value of Securities (BP)	1,000,000	1,000,000	1,000,000
Initial Spot Ex. Rate ($/BP)	1.6000	1.6000	1.6000
Final Spot Ex. Rate ($/BP)	1.6320	1.5680	1.6000
Initial Futures Price (F1)	1.6000	1.6000	1.6000
Liquidation Futures Price (F2)	1.6320	1.5680	1.6000
Initial Call Price (C1)	0.0228	0.0228	0.0228
Liquidation Call Price (C2)	0.0418	0.0098	0.0222
Futures Results 16 ctr · (F2 − F1) · 62,500	$32,000	($32,000)	$0
Calls Results 32 ctr · (C2 − C1) · 62,500	$38,000	($26,000)	($1,200)
Dollars Paid Unhedged	$1,632,000	$1,568,000	$1,600,000
Dollars Paid w/Futures Hedge	$1,600,000	$1,600,000	$1,600,000
Dollars Paid w/Calls Hedge	$1,594,000	$1,594,000	$1,601,200
Calls Hedge Results Minus Futures Hedge Results	$6,000	$6,000	($1,200)

time value will ultimately decline to zero. In a stable environment (one where the underlying instrument's price—and thus the intrinsic value—is constant, and where implied volatility remains unchanged), time value will diminish as time passes, with the rate of decay accelerating as option expiration approaches. This being the case, the delta-equivalent strategy may be most appealing (1) for relatively short risk exposures (i.e., days rather than weeks or months), (2) when the expiration date of the option is not imminent and (3) when the implied volatility appears to be relatively low, or at least not excessively high.

With these caveats, then, for virtually any relatively short-term exposure where futures contracts may be used to manage price risk, the substitution of delta-equivalent long option hedges for futures contracts offers the potential of either greater hedge gains than exposure losses or smaller hedge losses than exposure gains—the best of both worlds.

An Example

Consider a U.S. stock trader who buys British securities. The terms of the trade require the payment of £1 million in four days. As normal interbank settlement practice for British pounds requires a trade date two business days before the desired value date for the currency conversion, the unhedged investor would bear two days of risk that the pound would strengthen.

At the time the hedge is initiated, options on British pound futures have 39 days remaining to expiration; futures have 49 days to expiration. Spot and futures exchange rates are assumed to be $1.600 per pound. The implied volatility of the call options is 11%; at-the-money calls are thus priced at 2.28 cents per pound.

Table I demonstrates three possible outcomes, depending on whether British pounds strengthen (+2.0%), weaken (−2.0%) or remain stable with respect to the U.S. dollar. A number of simplifying assumptions are incorporated. Specifically, the scenarios assume that a zero basis persists (i.e., the spot exchange rate remains equal to the futures price) and the implied volatility of the option stays constant over the life of the hedge at 11%. The futures hedge ratio is found simply by dividing the £1 million by the size of the futures contracts (£62,500 per contract); this hedge ratio is doubled for the at-the-money call hedge.

Glossary

▶***At-the-Money:***
An option is at-the-money if the underlying instrument's price equals (or approximates) the option's strike price.

▶***Delta-Equivalent Fashion:***
Where the results of the option hedge are designed to replicate the results of the futures hedge, assuming an instantaneous, incremental change in the futures price.

▶***Futures Hedge:***
The use of a futures position in combination with an existing exposure, where the futures contract is expected to generate gains when the underlying exposure is losing value or generating losses.

▶***In-the-Money:***
An option is in-the-money if it has intrinsic value. For a call, the price of the underlying instrument would be higher than the strike price; for a put, the price of the underlying instrument would be lower than the price.

▶***Option Hedge:***
The use of an option position in combination with an existing exposure, where the option is expected to generate gains when the underlying exposure is losing value or generating losses.

▶***Out-of-the-Money:***
An option is out-of-the-money if it has no intrinsic value. For a call, the price of the underlying instrument would be lower than the strike price; for a put, the price of the underlying instrument would be higher than the strike price.

S&P ComStock/Micro Hedge Windows: results rooted in reliability.

Micro Hedge Windows is a fully networkable options analysis and risk management software from May Consulting and S&P ComStock. The software allows continuous assessment of opportunities while minimizing risks, particularly when market prices are fluctuating. Micro Hedge Windows offer theoretical values, delta, gamma, theta, four valuation models, implied volatility, volatility distribution, dynamic skew, trading sheets, sensitive variable analysis, profit/loss matrix and plot and derivatives.

At the hectic FINEX, a division of the New York Cotton Exchange, floor trader Bennett Gordon puts a lot of stock in Micro Hedge Windows, the fully networkable options analysis and risk management software from May Consulting and S&P ComStock, his real-time market data feed vendor.

"Having an advantage is what it's all about," Gordon says, referring to his information system's dependability. "When the dollar was going haywire recently, we knew where our positions were and could respond immediately if necessary."

Micro Hedge Windows was designed by a former CBOE trader to offer traders like Gordon the ability to update positions automatically. With real-time updates, Gordon is assured of reducing his risk and achieving a seamless integration of information that is crucial for continuous evaluation of opportunities.

In Gordon's business, rapid price and volatility changes can stimulate opportunities, but only for traders who can act swiftly.

"Micro Hedge Windows provides me with the ability to manipulate data I get from S&P ComStock and download it into an Excel spreadsheet so that I can better evaluate my positions and make more strategic decisions," Gordon says.

To provide traders with optimal flexibility and total control, S&P ComStock has introduced OpenArc !TM^, an advanced workstation based on Microsoft !R^ Windows !TM^ graphical user interface. OpenArc allows traders to pull real-time information off the screen and integrate it into the Micro Hedge application; Micro Hedge can also be built onto the OpenArc platform. OpenArc also includes a programmable quote page (up to 540 symbols per page), custom quote page, options analysis, S&P data, montage, news, charting and an on-line symbol directory.

Micro Hedge Windows features include theoretical values, delta, gamma, theta, four valuation models, implied volatility, volatility distribution, dynamic skew, trading sheets, sensitivity analysis for all variables, matrix and plot of profit/loss and all derivatives over time and more. Micro Hedge analytics are accessible via DDE (dynamic data exchange) interface.

"I don't think of my setup as being glitzy and that's not the point anyway," says Gordon. "What I do is buy and sell all day, and while that may not sound glamorous either, I do require an information system that will help bring some order to the demands of my job."

Conversations with traders like Gordon make it appear that successful market manipulation can be pinned down, in part anyway, to having the right vendor "connections" -- maybe not a revolutionary concept, but one to bank on nevertheless.

specific information from U.S.-based warehouses.

When asked if further legislation over U.S.-based warehouses might cause the LME to remove its delivery points, King said the warehouses would remain in the United States because their locations have been established to benefit users of the market.

Asked why Sumitomo might have decreased its dealings in U.S. markets and increased its use of the LME several months after the exchange opened its U.S. warehouses, King replied the firm may have been looking for a more liquid market.

"I don't believe they moved, if they moved, to a less regulated market, but to a more appropriately structured market that is designed for industrial clients," he said.

Susan Phillips, member of the board of governors of the Federal Reserve, said more regulation may not be the answer to preventing market manipulation.

"Regulation, however, simply cannot substitute for sound management. Early episodes clearly demonstrate the very same problems can occur in regulated as well as unregulated firms and with exchange-traded contracts as well as with privately negotiated contracts," Phillips testified.

"Thus, a more appropriate response — indeed, for nonfinancial companies the only practical response — is to continue to promote policies that foster greater market discipline."

Phillips also confirmed losses from the Sumitomo affair appear to be confined and had not spread to other firms.

By Carla Cavaletti

IT'S LIQUIDITY, STUPID

CBOE ups S&P limits

Trading in S&P options at the Chicago Board Options Exchange (CBOE) became much more liberal in September 1996. No, Hunter S. Thompson didn't become a market maker. The Securities and Exchange Commission (SEC) approved treating synthetic stock instruments, such as collars, as one instrument for hedge purposes.

Hedge trimmer:

Contracts allowed before and after

	Before	After
S&P 500 position limit	45,000	100,000
S&P 500 exercise limit	45,000	100,000
Index hedge exemption	150,000	250,000
Firm facilitation exemption	100,000	400,000
Money manager exemption	250,000	350,000

The number of positions CBOE users can put on is growing. The maximum for some firms now can be as high as 750,000.

Source: CBOE

➠ The SEC also approved increasing exercise and position limits as well as hedge exemptions at the CBOE. But treating synthetics as one instrument is the most significant approval, says Mary Bender, CBOE senior vice president of the regulatory services division.

"For the first time at the CBOE, we're able to take an equivalent position to an underlying basket and match it with the basket," Bender says. "This is a much more realistic treatment of the actual exposure of the position."

An example of a collar is a short call and a long put expiring together where the strike of the call is at least as much as the strike of the put. This type of instrument performs like a covered write position if the market rises and a long put if the market declines.

Before this change, a portfolio of securities could be matched up only with either the put or the call. Under the old exemption level of 150,000 for a single account (see "Hedge trimmer," page 16), a user could put on only 75,000 collars — 150,000 total puts and calls. The new treatment of synthetics and the increased hedge limits means users can put on 250,000 collars.

This change, as well as the increases in position and exercise limits and the larger hedge exemptions, are necessary if the CBOE is going to continue freeing its markets, according to the exchange.

"These increases are important to our exchange, making us more competitive with our counterparts in the futures markets, who have more flexible position limits," Bender says.

Not all market participants are happy with the changes. Howard Kotzen, executive vice president of securities, futures and options at ING Securities, Futures & Options Inc. in Chicago, says he agrees with increasing hedge exemptions and treating collars as one instrument but believes raising the position and exercise limits by 55,000 contracts gives traders too much leeway.

"Permitting people to put on larger sizes presents more risk to the clearing firm. You can't give traders a *carte blanche* as far as putting on size. Of course we have risk parameters, but those can't control what clients put on intraday," Kotzen says.

Now the overriding sentiment in the industry favors a delta-based position limit. In addition to lobbying harder for that, the CBOE will move to increase the limits in the S&P 100.

"We would always like to have less regulation and lower margins," says Richard Scarlata, director of research for Sutton Financial. "Recent changes are moving in that direction and will play a large part in attracting more institutional portfolio managers, especially the less-restrictive hedging requirements."

By James T. Holter

EXCHANGING FIRE

LIFFE and DTB vie for Euro traders

The question is not so much whether it will happen, but who ➠

Field of dreams? - There are numerous packages available that have been designed to take the nightmares out of options trading

PETER TEMPLE, CERI JONES
Investors Chronicle, P. 62, 11 December 1998

However experienced they might be in the equity market, investors keen on the idea of trading options find that the traded options market is rather different to the one they are used to.

Time is a critical variable in any option trade. An option has a limited lifespan, and its 'time value' erodes as the expiry date approaches, which means that the 'buy and hold' approach suitable for equity investments will not work in the options market. The options market requires disciplined trading, taking profits and cutting losses as they appear without letting emotion get in the way.

An understanding of how to read short term market movements and interpret the information that the market generates, is vitally important for successful trading. Most option professionals make extensive use of computer software to help them and a private trader who's new to the market should first become familiar with these techniques before they can hope to make money.

There are two main aspects to using software and market data effectively in the options market. One is becoming familiar with option pricing software; the second is being comfortable using technical analysis of price charts of the underlying securities to spot buying and selling opportunities that can be geared up through the options market.

Pricing model

Simple option pricing software helps the investor by defining - according to the information entered into it - a variety of different variables that can help a trader. The 'given' information is the price of an option, the underlying price, the strike price of the option and the length of time to expiry. From this information a simple pricing model can determine implied volatility and various measures of sensitivity. These can include, for example, the sensitivity of the price of the option to movements in the underlying price, or the speed at which the price of the option will decay over time.

Measuring volatility is important. If volatility is already high, then the chances are it will fall over time and work against a profitable outcome from the trade. A judgement therefore needs to be made, based on historical evidence, about whether or not the present level of volatility is high or low in terms of what has happened in the past.

Option pricing models are also very good at 'what if' scenarios. For instance, even the simplest model (look, for instance, at the various pricing calculators available at
www.numa.com) will allow you to enter
different values for the underlying security and its volatility, and

from that to calculate where the price of the option would be for given levels. This is a useful guide to working out a realistic view of the potential profitability of trades. Realism in this area is essential.

Charting packages

This is also where technical analysis packages come in. An option pricer needs to be used alongside a computerised charting package. This will graph the underlying share price and provide various technical indicators related to it, which will help to determine whether or not the shares are cheap or dear on a short term basis. One of the beauties of the options market is that it allows you to benefit from an overvalued share by buying a put option.

Many chart packages also allow the volatility of the share price to be calculated over time. Charting the course of the 90-day volatility in the share over a period of several years should provide a good guide to whether the present level of this parameter is low, high or about average.

Charts can also be used to identify trading ranges in shares either in terms of absolute price levels or in terms of movement to the upper or lower limits of currently establish trend channels. Many chart packages also allow trading volume parameters to be factored into the chart. Remember that price movements occurring on heavy volume carry more weight than those where volume is light.

Once again, like options, technical analysis is a large subject in itself and would-be option traders will find that investing in a good quality package and some books on the subject will pay-off in the long term. Some software suppliers also offer courses on technical analysis. Liffe publishes a guide to software suppliers producing packages suitable for use when trading options, details of which are available from 0171 623 0444 or from Liffe web site at www.liffe.com.

Why Market Maker Position Limits Should Be Delta-Based

Futures, Vol. 17, No. 9, PP. 42(2), August 1988
Ritchie, Joseph; Ginter, Gary
UMI Publication No.: 00415047
ISSN: 07462468
Subject Terms: Risk, Options markets, Limits, Investment advisors, Hedging
Classification Codes: 8130: Investment services; 3400: Investment analysis
UMI Journal Code: CMM

Abstract:

A key economic function of position limits in markets should be prevention of excessive amounts of risk among participants who are not prepared to manage that risk. A new method for establishing position limits for market makers in options is based on risk. It is proposed that risk be delta neutral and "gamma balanced." Delta is a measure of a position's current sensitivity to underlying price changes, and gamma is a measure of a position's propensity to change its delta or price exposure. By establishing different limits according to the market participants' economic functions, limits should reflect the distinct levels of participants' risk characteristics.
Market makers using the concepts of delta and gamma should focus on their total inventory risk, using a gamma-induced telescoping approach to reduce limits as expiration dates approach. Gamma-induced telescoping would require rolling positions forward into the out months where gamma risk is less.

NORTH-HOLLAND

International Review of Economics and Finance
12 (2003) 207–235

International Review of Economics & Finance

Calculation and comparison of delta-neutral and multiple-Greek dynamic hedge returns inclusive of market frictions

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Received 8 May 2001; received in revised form 20 May 2002; accepted 29 July 2002

Abstract

Evidence provided by traders in derivative-asset markets suggests that use of "delta-neutral" (DN) and "multiple-Greek" (MG) hedging strategies are a common and effective approach in achieving desired hedged investment goals. The principal objective of this research is to develop a model that calculates position returns for both DN and MG hedging effectiveness and incorporates Standard Portfolio Analysis of Risk (SPAN) margin requirements (MRs) as well as transaction costs (TCs). The results of this analysis show that a DN hedging approach activated by an increase in the implied volatility of the option produces a more effective hedge on a risk–return trade-off basis than the other hedging approaches examined.

JEL classification: G12; G13
Keywords: Delta-neutral; Multiple-Greek; Dynamic hedging; Margin requirements; Transaction costs

1. Introduction

Traders in derivative-asset markets employ a variety of dynamic strategies combining offsetting positions in options and/or futures to achieve desired "hedged" investment

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1059-0560/03/$ – see front matter
doi:10.1016/S1059-0560(03)00002-9

objectives. Evidence provided by market practitioners suggests that use of so-called delta-neutral (DN) and multiple-Greek (MG) hedging strategies is a common and effective approach. In fact, use of these general hedging approaches are so commonplace that discussion and examples of their application appear in the publication of London International Financial Futures and Options Exchange (LIFFE), which provides them to any interested party.[1]

DN strategies are derived from the well-known option-pricing model of Black and Scholes (1973) or specifically, the Black (1976) model for valuing interest rate options on futures contracts. "Delta" is the term used to refer to the partial derivative ($\partial C/\partial F$ or $\partial P/\partial F$) for the change in the option (call or put) price with respect to a change in the underlying asset (futures) price from the Black option-pricing model. The general goal of a DN hedging approach is to make a combined option/futures portfolio immune to changes in the underlying asset. However, a DN-hedged portfolio is only immune to small changes in the underlying asset over the next short time period. To maintain delta neutrality the portfolio position must frequently be adjusted or *rebalanced.* The counterbalance to the potential effectiveness of frequent portfolio rebalancing is the possibly large amount of transaction costs (TCs) that the position incurs as it is dynamically adjusted.

In practice, traders are also concerned with changes in the hedged portfolio's value in response to changes in other variables that affect option prices. Some of these other important partial derivatives relate to changes in delta itself (gamma), changes in time-to-expiration (theta), and changes in the volatility of the underlying asset (vega). This research also examines an approach that combines all of these partial derivatives into an MG hedge ratio based on an approach suggested in a LIFFE (1995) publication.

The objectives of this research are as follows. First, a model is developed for use by practitioners that allows the calculation of dynamically hedged-option position returns that specifically accounts for the effects of margin requirement (MR) costs/returns as well as TCs within the framework suggested in a 1995 report prepared by LIFFE and Price Waterhouse (1995). This model is then validated using short-term interest rate derivatives market-price data to ensure that the model produces results, which intuition suggests should be expected. Second, tests are conducted to determine if the inclusion of margin and TCs produces nontrivial differences in mean returns or return volatility. Third, the effectiveness of DN hedges is compared to MG hedges. Finally, two risk-activated strategies drawn from practitioner comments are developed and tested against several automatic rebalancing approaches and a passive approach for mean-variance hedging effectiveness.

First, the empirical findings show that there is a significant difference between mean returns (107 of 162 comparisons) and return variances (75 of 162 cases) for naked options and DN-hedged option positions when market frictions are included vs. the comparative cases where these frictions are ignored. Second, DN hedges are surprisingly found to produce both significantly higher means and lower return variances in a large majority (76%) of cases compared to the more theoretically justified MG hedges. Finally, comparison of risk-

[1] *Short-Term Interest Rates: Futures and Options—An Introduction and Strategy Examples* (LIFFE, 1995).

activated hedges to automatically rebalanced hedges and a passive hedging strategy shows that a DN hedging approach based on an increase in the implied volatility of the option produces a more effective hedge on a risk–return trade-off basis than the other hedging approaches examined.

2. Review of the literature

An important assumption of the Black and Scholes (1973) option-pricing model is that capital markets are perfect, i.e., that there are no TCs. Another assumption is that asset trading takes place continuously so that the replicating portfolio used to determine the option's price is also continuously rebalanced. Boyle and Emanuel (1980) consider the distribution of hedged portfolio returns when rebalancing takes place on a discrete basis and find it to be particularly skewed and leptokurtic. They examine whether weekly rebalancing is optimal. Boyle and Emanuel conclude that hedging errors will be reasonably small if rebalancing is relatively frequent and can be ignored if the errors are uncorrelated with market return. Gilster and Lee (1984) modify the Black and Scholes pricing model to include the effects of TCs (as well as different borrowing and lending rates). Their empirical tests show that TCs of daily rebalancing were reasonably small and that the discrete rebalancing frequencies of the continuous-time option-pricing model do not seem to be a problem. Leland (1985) argues that the Black and Scholes arbitrage-based option-pricing model is invalidated by the inclusion of TCs. He develops an alternative replicating strategy that depends on the level of TCs and the rebalancing frequency. His approach is essentially an adjustment to the volatility used in the Black and Scholes formula. Boyle and Vorst (1992) rework Leland's analysis in a binomial framework. Their adjustment to the variance used in the model differs from Leland's model because although the binomial assumption provides the correct variance, it changes the expected absolute price change in any subinterval. Benet and Luft (1995) examine DN hedging of SPX stock index options and S&P 500 index futures in the presence of MRs and TCs. They examine 1-, 2-, and 4-week rebalancing intervals. They also use substantial changes in delta as a rebalancing trigger. Using the Howard and D'Antonio (1984) risk–return measure, they find that with inclusion of option premiums, TCs, and initial MRs, futures hedges are more effective than option hedges. Clewlow and Hodges (1997) build upon an earlier work by Hodges and Neuberger (1989) that examines writing and hedging a European call option in the presence of proportional TCs. Clewlow and Hodges employ a stochastic optimal control approach for DN hedging portfolios in the presence of TCs. The strategies developed focus on a band within which delta must be maintained. A fixed TC component leads to rebalancing to the inner band when an outer control limit is reached. Gallus (1999) notes that in a complete market model based on geometric Brownian motion a delta-hedging strategy may be used to price many types of exotic options. However, he shows that for specific contingent-claims digital options, if the underlying asset does not follow the assumed price process then DN hedging may actually increase the risk of the option writer.

A number of these studies analyze the Black and Scholes (1973) option-pricing model in the presence of TCs. However, none of these studies explicitly focus on incorporating the

daily changes in MRs arising from the Standard Portfolio Analysis of Risk (SPAN) margining system using market prices for short-term interest rate options and futures. Further, none of these studies develop a model that allows practitioners to determine position returns in a manner that reflects the accounting recommendations developed by LIFFE in conjunction with Price Waterhouse.

3. The model and "market imperfections" considered

3.1. Two risk-activated hedging strategies

To analyze DN and MG hedging effectiveness, the model developed here is based explicitly on the example cited on pages 67–69 in *Short-Term Interest Rates: Futures and Options—An Introduction and Strategy Examples* (LIFFE, 1995). In this example, the position is rebalanced on a daily basis using settlement prices. Through informal interviews, several traders have offered anecdotal evidence that suggests two important considerations when they trade. First, one trader who admitted that he had conducted analysis similar to this research concluded that 3-day (2-day) rebalancing is optimal for at-the-money calls (puts) when comparing automatic, daily rebalancing schemes. His comments suggest that daily rebalancing strategies may be employed by some traders. Second, the traders suggested that position risk is an important aspect of why they use dynamic, DN, or MG hedging techniques. They agreed with the author's suggestion that hedge rebalancing in response to increased risk might be a practical and potentially useful approach. Therefore, two dynamic, nonautomatically rebalanced trading strategies are devised that focus upon the risk characteristics of the overall hedged position.[2]

There are two objective measures of market volatility that a hedger in the LIFFE markets might utilize daily to determine if the hedge should be rebalanced. The first measure is whether the overall position's daily MR has increased according to the SPAN margining system because of its increased risk. As is noted in the proceeding discussion, the position's MR is recalculated every day based on the position's maximum loss (ML) under 16 different SPAN risk scenarios. If the maximum (potential) loss rises, then traders are required to post increased margin. Thus, an increase in the ML is an obvious risk indicator upon which to base a positional rebalancing. The first risk-activated strategy is then to rebalance the hedged position whenever the maximum loss (termed the *maximum loss* strategy) indicated by the SPAN system increases. The second measure is based on changes in the implied volatility of the option for which the futures contract is the underlying asset. Changes in the option's implied volatility may be taken as indication of increased risk, and therefore, also act as a rebalancing trigger. The second risk-activated hedging strategy, termed the *increased volatility* (IV) hedge, is then to rebalance the hedged position whenever the implied volatility of the option increases.

[2] These approaches are conceptually similar to that analyzed in Benet and Luft (1995).

An additional point that must be noted is that the hedging strategies analyzed here are based on using end-of-day (settlement) price data. For example, Black and Scholes (1972) assume that the hedged portfolio in their empirical tests is rebalanced on a daily basis. Other researchers including Boyle and Emanuel (1980) and more recently, Clewlow and Hodges (1997) focus on (minimal) daily hedge rebalancing. In fact, the minimum, automatic rebalancing frequency considered by Benet and Luft (1995) and Leland (1985) is 1 week.

Clearly, large institutional investors could be expected to base their position rebalancing on intraday price changes and adjust them accordingly. However, potential intraday rebalancing would necessarily increase the TCs of any strategy analyzed and quite probably to a significant extent. Evidence from practitioners suggests that some DN traders do in fact use end-of-day position adjustment.[3] This fact should not be taken as indicating that intraday price changes are unimportant. Rather, it may suggest that typical practice for some hedgers is to focus on end-of-day rebalancing. In any event, in this study, no strategy will enjoy a comparative advantage because they are all based on end-of-day data.

To develop the final model utilized here, the following sections describe, respectively, the hypotheses analyzed, the SPAN system for determining initial MRs, the TCs, and data sets employed. This discussion is then followed by development of the equations and overall return model incorporating all MRs/TCs.

3.2. Hypotheses analyzed

In this analysis, several issues regarding hedging effectiveness are considered. To more clearly focus on each of these issues, the hypotheses examined here are enumerated specifically as follows. In a practical application of DN or MG hedging, a trader will incur TCs and cash inflows/outflows related to initial and variation margins, which will be dependent on the frequency of portfolio rebalancing. These costs and cash flows may seriously affect the returns earned on the hedged portfolio. Thus,

Hypothesis 1: A comparison of hedged returns that include these transaction and margin costs/returns to the returns earned on the portfolio without considering these costs will show that mean returns and return variances differ significantly.

A DN hedging strategy rebalances the portfolio based on the option's sensitivity to changes in the underlying futures contract. Theoretically, an MG hedging approach should be superior as it also takes into account changes due to decreasing time-to-expiration, implied volatility, and changes in delta itself. Hypothesis 2 then follows:

Hypothesis 2: The MG hedging strategy is expected to produce significantly higher mean returns and/or significantly lower return variances in comparison to a DN hedging strategy.

[3] Additionally, London SPAN "risk arrays are calculated centrally each day using the closing market prices to illustrate how much the portfolio would gain or lose using the closing market prices and initial margin parameters" (LIFFE, 1996, p. 38).

There is a trade-off between return-variability reduction benefits through increased frequency of rebalancing and the higher TCs of this frequent rebalancing. These higher costs will necessarily lower the portfolio's return. The determination of a superior hedging approach should clearly consider the risk–return trade-off. The hedging benefit per unit of risk (termed *HBS*) developed by Howard and D'Antonio (1987) is utilized here for this purpose. As the HBS measure includes both risk and return in its calculation, it is an empirical question whether increased returns or decreased volatility will dominate the generation of superior HBS measures. Automatic rebalancing schemes may tend to increase TCs unnecessarily in comparison to risk-triggered hedging approaches and both will certainly generate greater TCs than a passive hedging strategy. However, increased rebalancing frequency is expected to reduce position variance. Hypothesis 3 may be stated as:

Hypothesis 3: Hedges based on increased-risk rebalancing are expected to provide a superior risk–return trade-off compared to automatic hedge rebalancing strategies.

Where appropriate, findings in the Results section will be referenced to the particular hypothesis that is being tested.

3.3. Determining initial MRs via the SPAN system and variation margin

3.3.1. The London Clearing House

The primary purpose of the London Clearing House (LCH) is to act, in relation to its members, as central counterparty for contracts traded on London's futures and options exchanges. To limit and cover the potential loss, LCH collects margin on all open positions and recalculates members' margin liabilities on a daily basis. The two major types of margin are initial and variation margin.

3.3.1.1. Initial margin requirements.

Span parameters and scanning range. LCH uses London SPAN to calculate initial MRs for LIFFE.[4] London SPAN builds on and adapts the SPAN framework developed by the Chicago Mercantile Exchange (Chicago Board Options Exchange, 1995). In conjunction with the exchange, LCH sets initial margin parameters for each contract. The two main parameters are a futures price move, known either as the *initial margin rate* or the *futures scanning range*, and an *implied volatility shift*. These are set with reference to historical data on prices and volatilities and other factors such as known price-sensitive events. The parameters are kept under continuous review by LCH but do not change on a daily basis. London SPAN parameters as of 25 February 1997 are used in the analysis throughout for consistent calculation of returns.

London SPAN divides contracts into groups of futures and futures options relating to a single underlying asset (e.g., Short Sterling futures and options on Short Sterling futures). These groups are referred to as "portfolios." At the first stage of calculation, London SPAN simulates how the value of a portfolio would react to the changing market conditions defined

[4] This section draws upon *Understanding London SPAN* published by the London Clearing House (1994).

Scenario	Futures Price Changes	Implied Volatility Changes
1	Futures price down 3/3 range	Volatility up
2	Futures price down 3/3 range	Volatility down
3	Futures price down 2/3 range	Volatility up
4	Futures price down 2/3 range	Volatility down
5	Futures price down 1/3 range	Volatility up
6	Futures price down 1/3 range	Volatility down
7	Futures price unchanged	Volatility up
8	Futures price unchanged	Volatility down
9	Futures price up 1/3 range	Volatility up
10	Futures price up 1/3 range	Volatility down
11	Futures price up 2/3 range	Volatility up
12	Futures price up 2/3 range	Volatility down
13	Futures price up 3/3 range	Volatility up
14	Futures price up 3/3 range	Volatility down
15	Futures up extreme move	Volatility unchanged
16	Futures down extreme move	Volatility unchanged

Fig. 1.

in the initial margin parameters. This is done by forming a series of market scenarios and evaluating the portfolio under each set of conditions.

London SPAN uses 16 market scenarios in conjunction with the scanning range and volatility shift parameter to determine the potential profits/losses for each contract (futures month or option series) by comparing the current (market) price with the calculated contract price under each scenario. Futures prices are determined directly through the various scenarios. Option prices are calculated using the Black (1976) model based on the various futures prices and volatilities in the 16 scenarios. The 16 profits/losses for each contract then form a *risk array.* Fig. 1 above details the 16 market scenarios used in the calculation of London SPAN to form the risk array.

Risk arrays and scanning risk. Risk arrays are calculated each day using the closing futures and options prices. By valuing each net position (future or option) with the appropriate array and then combining arrays, London SPAN determines which scenario generates the ML for the portfolio, which may consist of either naked or combined positions. This ML is then referred to as the *scanning risk.* Scanning risk is the principal input into the calculation of the initial MR. Under SPAN, the initial MR changes each day as rates move and as the relative values of the portfolio components change. Changes in the initial MR need to be funded as long as positions remain open.[5]

3.3.1.2. Variation margins. Each day, open futures and options contracts are "marked-to-market" and daily profits or losses are paid through variation margin. For LIFFE financial options, payment of premium on initiation is not mandatory. If an option gradually becomes

[5] *Futures and Options—Accounting and Administration* (LIFFE & Price Waterhouse, 1995, p. 7).

Short Sterling	£ 3.00
Euromark	DM 8.00
Euroswiss	Sf 6.50

Fig. 2.

worthless, then the premium is effectively paid over time via the variation margin.[6] Having determined the profit or loss on a marked-to-market basis, the whole of the profit or loss should be recognized immediately. This recognizes the fact that each day a trader effectively decides either to keep a position open or to close it.[7] Changes in variation margin, therefore, need to be explicitly accounted for in the daily portfolio-return calculations.

3.4. Transaction costs

A sample of brokerage firms in Ireland and the United Kingdom was contacted in an effort to determine typical institutional TCs. Several firms responded and the round-trip costs used in this analysis are essentially an average of those provided. The derivative contracts examined here are denominated in their own domestic currency, so the TCs in the three relevant currencies are given above in Fig. 2.[8]

3.5. Data sets analyzed

The daily closing (settle) prices, as well as other data, e.g., implied volatilities for the futures options and contracts examined here are provided by LIFFE. The short-term interest rate markets analyzed are the 3-month Short Sterling, Euromark, and Euroswiss contracts. In each market, the period considered essentially dates from the inception of futures option trading. For Short Sterling, analysis begins with the March 1989 contract. Euromark and Euroswiss analysis begin with the March 1991 and September 1993 contracts, respectively. Analysis for all contracts ends with the March 1998 contract inclusive.

For each contract maturity, three calls and three puts are chosen for analysis. The contracts chosen are those with the three strike prices closest to the average futures (underlying asset) price over the period of analysis.[9] For each contract, a period of 130 trading days is analyzed, which typically commences about 280 (calendar) days from the option's expiration. This

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6 Ibid.

7 Ibid. (p. 21).

8 These transaction costs are somewhat lower than those employed by Benet and Luft (1995) who report that interviewed market participants put round-trip transaction costs at \$8–10.

9 Options that are close to being "at-the-money" are utilized in this analysis to avoid the possibility that it might be optimal to exercise any of the puts early. Hull (1997, pp. 162–66) shows that it will never be optimal to exercise a call (on a non-dividend-paying stock) early and only optimal for a similar put if it is sufficiently deeply in-the-money.

normally corresponds to the advent of trading in the contract and this approach insures that final portfolio reversal occurs well before the expiration month. The objective of using this investment period is to minimize the compression in option deltas (to their value at expiration) as expiration approaches. In addition, to minimize any potential beginning- or end-of-the-week effects, all positions are initiated on a Wednesday. Once the returns for a given contract have been calculated, they are aggregated into a composite file for each option. Return analysis described in the Results section is then based on these composite return files. This approach conforms with the LIFFE guidelines stated as: "A suitable report to management evaluating hedge performance should contain details of:. . .the hedge efficiency being achieved, the trend over time being a more significant measure of performance than the result of any individual open hedging transaction."[10]

3.6. Portfolio return model

3.6.1. Theoretical option-pricing model

The Black (1976) pricing model is the most widely used and recognized option-pricing model for LIFFE options. The models for pricing short-term interest rate options[11] are as follows:

$$C = [(100 - X) \times N(-d_2)] - [(100 - F) \times N(-d_1)], \text{ and} \tag{1}$$

$$P = [(100 - F) \times N(d_1)] - [(100 - X) \times N(d_2)], \tag{2}$$

where

$$d_1 = \left[\frac{\ln\left(\frac{R_f}{R_x}\right) + \frac{1}{2}S^2T}{S\sqrt{T}}\right],$$

$$d_2 = d_1 - (S\sqrt{T}),$$

$$N(-d_1) = 1 - N(d_1) \text{ and}$$

$$N(-d_2) = 1 - N(d_2),$$

with C as the call premium, P as the put premium, F as the futures price, X as the strike price, R_f as the rate implied by futures price (i.e., 100 − futures), R_x as the rate implied by strike price (i.e., 100 − strike), S as the volatility of 3-month rates measured by annual standard deviation, T as the time to expiration in years, and $N(d)$ as the cumulative probability distribution function for a standardized normal variable.

[10] *Futures and Options—Accounting and Administration* (LIFFE & Price Waterhouse, 1995, p. 41).

[11] *Short-Term Interest Rates: Futures and Options* (LIFFE, 1995, p. 64). See also Stoll and Whaley (1993, p. 372) for similar valuation formulas.

Actual LIFFE market prices are used in all portfolio-return calculations. However, as noted above, the Black (1976) model prices are used by the SPAN system to determine initial MRs. In this model, the underlying futures prices are assumed log-normally distributed. The partial derivatives[12] of this version of the Black model with respect to F(Delta) are as follows:

$$\delta_C(\text{Delta}) = \partial C/\partial F = N(-d_1). \tag{3}$$

$$\delta_P(\text{Delta}) = \partial P/\partial F = -N(d_1). \tag{4}$$

Delta is the expected change in the option's value for a small change in the futures price and serves as the hedge ratio in the DN hedging strategy. Delta sensitivity for a long call (long put) position is positive (negative), meaning that the call position benefits from an increase in the futures price whereas the put position loses.

3.6.2. Calculation of the MG hedge ratio

Option values are also sensitive to changes in other variables in the model. Theta is the expected change in the option's value as the time-to-expiration decreases. The sensitivity of both calls and puts to a decrease in time-to-expiration is negative. The calculation of theta is given in Eq. (5) and is the same for both calls and puts (as is also true of vega and gamma that follow).

$$\text{Theta}_C(\partial C/\partial T) = \text{Theta}_P(\partial P/\partial T) = [R_X \times S \times Z(d_1)]/(2\sqrt{T}), \tag{5}$$

where

$$Z(d_1) = \partial N(d_1)/\partial d_1 = \left[\frac{e^{-(d_1)^2/2}}{\sqrt{2\pi}}\right].$$

Vega (sometimes called *kappa*) represents the expected change in the option's value for a 1% change in the option's volatility. There is a direct relationship between option volatility and option value. Eq. (6) shows the calculation of vega utilized in this research.

$$\text{Vega}_C(\partial C/\partial S) = \text{Vega}_P(\partial P/\partial S) = R_F \times \sqrt{T} \times Z(d_1). \tag{6}$$

Gamma is defined as the expected change in the option delta for an incremental change in the value of the underlying asset. A long call or put position will have positive gamma sensitivity, meaning that delta increases if the underlying futures price increases.

$$\text{Gamma}_C(\partial \Delta_C/\partial F) = \text{Gamma}_P(\partial \Delta_P/\partial F) = Z(d_1)/(R_F \times S \times \sqrt{T}). \tag{7}$$

The approach suggested by LIFFE for aggregating these four sensitivities into a combined hedge ratio is surprisingly simple. "The overall sensitivity of a portfolio can be obtained by

[12] Ibid. LIFFE also provides calculated deltas as part of the daily settlement price information it supplies to interested parties. Note that the deltas in Eqs. (3) and (4) differ from traditional "stock option" deltas, but are consistent with the short-term interest rate option valuation formulas given in Eqs. (1) and (2) above, as well as those in Stoll and Whaley (1993, p. 372).

adding up the delta, gamma, theta, and vega of each individual option position on the same underlying (asset)" (LIFFE, 1995, p. 66). Thus, the multiple-Greek hedge ratios (MGHR) for hedging calls and puts are calculated as in Eqs. (8) and (9) below.

$$\mathrm{MGHR}_C = \mathrm{Delta}_C + \mathrm{Gamma}_C - \mathrm{Theta}_C + \mathrm{Vega}_C. \tag{8}$$

$$\mathrm{MGHR}_P = \mathrm{Delta}_P + \mathrm{Gamma}_P - \mathrm{Theta}_P + \mathrm{Vega}_P. \tag{9}$$

In the models developed below, the discussion is couched in terms of DN hedges, but it applies equally to MG hedges. The only difference in the model (and the analysis that is conducted) is that the MG hedge ratio is substituted for the DN hedge ratio.

3.6.3. Initial and variation margins

As discussed above, SPAN initial margins are calculated on a daily basis for naked or combination positions. In the analysis here, return comparisons are made for naked option positions vs. futures-hedged portfolio positions. The formulas presented below are therefore developed for option-only positions and for hedged positions. Assume that time i represents any day between initiation at time 0 and final position closure after n days. Time k is some date greater than or equal to day 2, and is less than or equal to day n. To represent cumulative returns of day 0 through day i, k is used, where the overall investment is n days. Reversal i refers to the daily reversal from a position opened on day $i-t$ and reversed on day i, whereas t represents the number of days elapsing since the most recently preceding trading day. It should be noted that the detailed formulas below generally relate to a long call position hedged using short futures and a daily DN rebalancing frequency. The initial SPAN MR for a call-only position (SPAN call-only margin, or SCOM) is given in Eq. (10) and the SPAN initial hedge margin (SIHM) is given in Eq. (11).

$$\mathrm{SCOM}_i = \mathrm{Max\ Loss}_i(\mathrm{SPAN\ Call\ Loss}_i). \tag{10}$$

$$\begin{aligned}\mathrm{SIHM}(x)_i &= \mathrm{Max\ Loss}_i(\mathrm{SPAN\ Call\ Loss}_i + \mathrm{SPAN\ DN\ Future\ Loss}_x)\\ &= \mathrm{Max\ Loss}_i(\mathrm{SCL}_i + \mathrm{SFL}_i),\end{aligned} \tag{11}$$

where $\mathrm{SIHM}(x)_i$ is the SPAN initial hedge margin (recalculated daily) for reversal i and rebalancing frequency x.

Note that the scenario generating the ML SPAN call-only margin in Eq. (10) will not necessarily be the same scenario as that generating span call loss in Eq. (11). The SPAN scenario where the ML occurs could easily differ where the call-only position is held compared to where the call position is combined with offsetting futures into a portfolio. Six different automatic rebalancing frequencies are examined. DN H1A refers to daily-adjusted hedges where the returns include all TCs and margin returns/costs. DN H2A, H3A, H4A, and H5A refer to DN hedges with a 2-day, 3-day, weekly, and biweekly rebalancing frequency, respectively. DN H6A refers to a DN strategy, which when initiated is DN but may be termed passive as the futures position is not subsequently adjusted. The ML strategy is then labeled DN H7A, and DN H8A refers to the IV approach.

The call-only daily variation margin (CDVM) is given as follows:

$$\mathrm{CDVM}_i(\text{Long Calls}) = (-C_{i-t} + C_i)\mathrm{CP} \times \mathrm{TV} \times 100, \tag{12}$$

where C_i is the settle call futures option price on day i, CP is the call (or put) position (assumed to equal 100 contracts), and TV is the tick value.

Multiplication of the daily positional profit/loss by 100 is used to convert tick value to an actual (£Stg./DM/Sf) value. Cumulative variation margin then represents net profit/loss to date. Call-only cumulative variation margin (CCVM) from initiation at $i=0$, to the reversal at k, is then given as:

$$\mathrm{CCVM}_{i,k} = \sum_{i=1}^{k} \mathrm{CDVM}_i = \gamma_{i,k}. \tag{13}$$

The next necessary distinction regards the initial (base or non-delta-adjusted) futures position vs. the delta-adjusted futures component. The initial futures daily variation margin (IFDVM) is given in Eq. (14). Then the initial futures cumulative variation margin (IFCVM) at reversal k is given in Eq. (15). Since the call or put is assumed to be held long, the futures hedge for a call (put) is assumed to be a short (long) position and this is reflected in the IFP term.

$$\mathrm{IFDVM}_i = (-F_{i-t} + F_i)\mathrm{IFP} \times \mathrm{TV} \times 100, \tag{14}$$

$$\mathrm{IFCVM}_{i,k} = \sum_{i=1}^{k} \mathrm{IFDVM}_i = \phi_{i,k}, \tag{15}$$

where F_i is the settle short-term interest rate futures on day i and IFP is the initial futures position (initial delta$(-\mathrm{CP})$).

The daily delta adjustment (DA_i) for reversal i and then the cumulative delta adjustment (CDA) as of reversal k are given in turn.

$$\mathrm{DA}_i = (\delta_{i-t} - \delta_i)(-\mathrm{CP}). \tag{16}$$

$$\mathrm{CDA}_{i,k} = \sum_{i=1}^{k} [(\delta_{i-t} - \delta_i)(-\mathrm{CP})] = \varphi_{i,k}. \tag{17}$$

The call position term appears in Eqs. (16) and (17) to convert the decimal values of the daily delta adjustment to a contract basis. The ith delta-adjusted daily variation margin (DADVM) as of reversal k is then shown in Eq. (18).

$$\mathrm{DADVM}_{i,k} = \varphi_{i,k}[(-F_{i-t} + F_i)\mathrm{TV} \times 100]. \tag{18}$$

The delta-adjusted cumulative variation margin (DACVM) as of reversal k then follows in Eq. (19).

$$\mathrm{DACVM}_{i,k} = \sum_{i=1}^{k} \mathrm{DADVM}_i = \eta_{i,k}. \tag{19}$$

3.6.4. Return on initial and variation margins

The returns/costs on initial and variation margins are the next input to overall calculation of the positions' returns in the model. The approach used here to account for these returns or costs is based on guidelines suggested by LIFFE. In general, the initial margin is treated as a use of cash and thereby generates an opportunity cost of funds. Capital gains/losses from futures or options positions as represented by changes in the variation margins are assumed to be allocated to the cash account.[13] The question arising then in determining the corresponding costs/returns for these cash flows is "What cash interest rate to use?" The LIFFE suggestion is that "a notional rate must be used. . .that should be the rate earned on the rest of the cash part of the portfolio."[14] The notional margin rate (r_m) adopted here from the LIFFE Recommendations (1992, p. 32) is an annual rate of 3%.

The equations used for calculating margin costs/returns are explicitly formulated to account for the considerations enumerated above, namely daily revision of the initial SPAN MR and changes in the variation margin. Thus, the return for each daily reversal is calculated and then summed up to reflect the return calculation as of reversal k. For the naked option position, the cumulative option SPAN initial margin cost (COIMC) is shown in Eq. (20).

$$\mathrm{COIMC}_{i,k} = \sum_{i=1}^{k}[\mathrm{SCOM}_i(r_\mathrm{m}(i-(i-t))/365)] = \kappa_{i,k}. \tag{20}$$

Similarly, the cumulative hedge SPAN initial margin cost (CHIMC) for rebalancing frequency x as of reversal k is given as:

$$\mathrm{CHIMC}_{i,k} = \sum_{i=1}^{k}[\mathrm{SIHM}(x)_i(r_\mathrm{m}(i-(i-t))/365)] = \lambda_{k,n}. \tag{21}$$

Given the above considerations, the same calculation approach leads to the formulas for the cumulative option variation margin return (COVMR) in Eq. (22) and the cumulative hedge variation margin return (CHVMR) in Eq. (23).

$$\mathrm{COVMR}_{i,k} = \sum_{i=1}^{k}[(\gamma_i)(r_\mathrm{m}(i-(i-t))/365)] = \theta_{i,k}. \tag{22}$$

$$\mathrm{CHVMR}_{i,k} = \sum_{i=1}^{k}[(\gamma_i+\phi_i+\eta_i)(r_\mathrm{m}(i-(i-t))/365)] = \nu_{i,k}. \tag{23}$$

3.6.5. Transaction costs

The estimated TCs employed in the model are given above on a round-trip basis. This cost approach simplifies the calculation of the returns, which are analyzed on the basis of daily position reversal. To deal with the different positions analyzed, TCs are subdivided into three

[13] *The Reporting and Performance Measurement of Financial Futures and Options in Investment Portfolios* (LIFFE Recommendations, 1992, pp. 29, 36–41).

[14] Ibid. (p. 34).

categories. These components are the following: initial option position TCs (OTC), base futures position TCs (BFTC), and delta-adjusted futures TCs (DAFTC). Thus, total hedge transaction costs (THTC) as of reversal k are given as:

$$\mathrm{THTC}_{i,k} = \mathrm{OTC}_{i,k} + \mathrm{BFTC}_{i,k} + \mathrm{DAFTC}_{i,k}. \tag{24}$$

3.6.6. Return calculation model

In the finance literature, it is well recognized that return calculations involving futures and options are somewhat difficult due to the fractional margin required to support the larger "market-value" of derivative positions. LIFFE Recommendations (1992, p. 31) stipulate that "it is not possible to measure performance on a 'margin payment' basis, i.e., by using the capital gain on the futures position against either that of the equity or the cash components of the portfolio. This would lead ultimately to nonsensical figures for the return on parts of the portfolio....Therefore, an **adjustment must be made to an associated economic exposure basis, equivalent to that made in the reporting process**" (emphasis in the original). To account for this, the market-value economic exposure is directly reflected here for naked options or on a "net-basis" in the hedged portfolio returns.

Tests of Hypothesis 1 for the significance of including TCs and margin returns, require comparison of the relevant returns with, and without, inclusion of those costs and/or returns. The efficacy of DN and MG hedging strategies is tested by calculating returns for naked-option positions as well as for the corresponding futures-hedged portfolio positions. The four return models below are developed to deal with these considerations. The long call and put returns without TCs/MRs as of reversal k are given in Eqs. (25) and (26), respectively.

$$R(C)_{\mathrm{NTC},k} = \left[\frac{(-C_0 + C_k)}{C_0}\right]\left[\frac{365}{k}\right]. \tag{25}$$

$$R(P)_{\mathrm{NTC},k} = \left[\frac{(-P_0 + P_k)}{P_0}\right]\left[\frac{365}{k}\right], \tag{26}$$

where P_k is the settle put futures option price on day k.

The return calculation for the call-only position inclusive of all TCs and MRs is given in Eq. (27).

$$R(C)_{\mathrm{ATC},k} = \left[\frac{(\gamma_{i,k} + \theta_{i,k} - \kappa_{i,k}) + (-\mathrm{SCOM}_0 + \mathrm{SCOM}_k) - \mathrm{OTC}_k}{((C_0 \times \mathrm{CP} \times \mathrm{TV} \times 100) + \mathrm{SCOM}_k) + \gamma_{i,k}}\right]\left[\frac{365}{k}\right]. \tag{27}$$

Two points of clarification should be mentioned concerning the formulation given in Eq. (27). First, the difference between the SPAN MR at initiation and at reversal is included in the numerator to account for the daily recalculation as described earlier. Second, the SPAN initial

MR as of reversal at day k is included in the denominator because it represents the amount of funds tied up in initial margin as of that date. Further, SCOM_k is considered part of the investment since the cost of funds tied up in initial margin as represented in the $\kappa_{i,k}$ term are in the numerator.

The return on a delta-adjusted hedge where TCs/margin returns are ignored (NTC) is given in Eq. (28). The absolute value of the long call position offset by the short futures is used in the denominator to reflect the net economic exposure basis of the offsetting positions of the hedged portfolio.

$$R(H)_{\mathrm{NTC},k} = \left[\frac{\eta_{i,k}}{(|(C_0 \times \mathrm{CP}) + (F_0 \times \mathrm{IFP})|\mathrm{TV} \times 100)}\right]\left[\frac{365}{k}\right]. \tag{28}$$

Finally, the return on the delta-adjusted hedge considering all TCs and margin returns (ATC) is given in Eq. (29) as follows.

$$R(H)_{\mathrm{ATC},k} = \left[\frac{(\gamma_{i,k} + \phi_{i,k} + \eta_{i,k} + \nu_{i,k} - \lambda_{i,k}) + (-\mathrm{SIHM}_0 + \mathrm{SIHM}_k) - \mathrm{THTC}_k}{((|(C_0 \times \mathrm{CP}) + (F_0 \times \mathrm{IFP})|\mathrm{TV} \times 100) + \mathrm{SIHM}_k) + \eta_{i,k}}\right]\left[\frac{365}{k}\right]. \tag{29}$$

It may be noted that the preceding formulations all utilize the initial option and/or futures prices as the base for the return calculations. Clearly, this approach yields return calculations that are effectively decreased in magnitude by the annualization factor as the reversal date gets farther from the initiation date. The calculation approach is derived from the method suggested in LIFFE Recommendations (1992, p. 49). The approach obviously compresses the returns that could be calculated alternatively on the basis of using the daily return calculated as $[(P_{i-t} - P_i)/P_{i-t}]$ where P_i equals the price on day i. However, since all returns here are calculated on a similar basis, they are comparable and do not reflect any particular bias arising from the calculation approach regarding the hypotheses examined.

4. Results

Discussion of the analysis of returns on short-term interest rate contract hedging generally proceeds in order of the hypotheses proposed earlier. Hypothesis 1 states that it is expected that there will be a significant difference between position returns and return variability where a comparison is made of returns that include TCs/MRs (termed *inclusive returns*) to returns excluding (termed *exclusive returns*) them. Evidence regarding this hypothesis is given for the at-the-money calls and puts in Table 1. This table provides annualized returns and standard deviations for naked option positions as well as the DN- and MG-hedged portfolios for each of the eight strategies. An indication of whether the

Table 1
Risk–return measures for unhedged options vs. DN and MG futures-hedged portfolios

Option/hedge	DN hedges		MG hedges		Option/hedge	DN hedges		MG hedges	
	Rtn (%)	S.D. (%)	Rtn (%)	S.D. (%)		Rtn (%)	S.D. (%)	Rtn (%)	S.D. (%)
Market: Short Sterling									
Call 2A	−38.856**	1268.535**	−38.856**	1268.535**	Put 2A	69.890	1760.818**	69.890	1760.818**
Call 2B	114.901	1160.517	114.901	1160.517	Put 2B	69.997	736.201	69.997	736.201
H1A	−0.435**	2.744	−0.606	3.445	H1A	−0.204*	3.381	7.608**	47.291**
H1B	−0.287	2.775	−0.508	3.418	H1B	−0.050	3.451	16.142	81.642
H2A	−0.348**	2.932	−0.537	3.423	H2A	−0.244*	3.327	7.496**	47.372**
H2B	−0.205	2.983	−0.445	3.400	H2B	−0.098	3.393	16.019	81.637
H3A	−0.305*	2.899	−0.513	3.373	H3A	−0.261*	3.323	7.119**	46.591**
H3B	−0.168	2.938	−0.425	3.351	H3B	−0.118	3.387	15.340	79.431
H4A	−0.317*	3.172*	−0.525	3.392	H4A	−0.239*	3.307	7.733**	47.636**
H4B	−0.177	3.263	−0.439	3.370	H4B	−0.101	3.369	16.449	82.038
H5A	−0.224	3.418**	−0.462	3.348	H5A	−0.240	3.201	7.342**	46.903**
H5B	−0.089	3.549	−0.387	3.333	H5B	−0.117	3.267	15.958	81.113
H6A	−0.033	4.530**	−0.334	3.250	H6A	−0.314*	2.273	6.206**	44.357**
H6B	0.134	4.933	−0.264	3.240	H6B	−0.214	2.291	13.276	67.918
H7A	−0.388*	2.829	−0.575	3.489	H7A	−0.194*	3.404	7.201**	48.194**
H7B	−0.254	2.860	−0.486	3.465	H7B	−0.052	3.475	16.058	83.006
H8A	−0.363*	2.914	−0.543	3.396	H8A	−0.216	3.336	7.837**	47.486**
H8B	−0.243	2.953	−0.467	3.375	H8B	−0.091	3.398	16.259	81.201
Market: Euromark									
Call 2A	−46.620**	952.406**	−46.620**	952.406**	Put 2A	−8.744**	587.822**	−8.744**	587.822**
Call 2B	209.327	1168.265	209.327	1168.327	Put 2B	−76.190	511.195	−76.190	511.195
H1A	−0.430**	2.051	−0.917*	2.964	H1A	−0.524**	1.722	−3.923	43.20**
H1B	−0.196	2.023	−0.777	2.893	H1B	−0.374	1.678	−3.721	46.88
H2A	−0.367**	2.167	−0.873*	2.851	H2A	−0.517**	1.706	−3.534	42.06**
H2B	−0.147	2.155	−0.744	2.792	H2B	−0.376	1.663	−3.337	46.04
H3A	−0.450**	2.003	−0.932	3.019	H3A	−0.511**	1.708	−3.144	41.30**
H3B	−0.240	1.957	−0.807	2.956	H3B	−0.374	1.663	−2.954	45.52
H4A	−0.345**	2.191	−0.851	2.809	H4A	−0.534**	1.686	−3.861	42.61**
H4B	−0.139	2.176	−0.731	2.759	H4B	−0.400	1.642	−3.558	46.38
H5A	−0.323**	2.237	−0.830	2.776	H5A	−0.530**	1.662	−3.385	41.38**

H5B	−0.130	2.215	−0.724	2.740	H5B	−0.406	1.619	−3.111	45.64
H6A	0.196*	4.524**	−0.430*	2.106	H6A	−0.454**	1.504*	−2.997	40.04**
H6B	0.447	4.971	−0.338	2.101	H6B	−0.342	1.453	−2.304	44.64
H7A	−0.531**	1.959*	−0.981	3.078	H7A	−0.500**	1.665	−3.761	42.80**
H7B	−0.327	1.894	−0.859	3.013	H7B	−0.366	1.620	−3.338	46.61
H8A	−0.371**	2.067	−0.859	2.907	H8A	−0.501**	1.708	−4.033	42.91**
H8B	−0.190	2.007	−0.755	2.864	H8B	−0.381	1.665	−3.804	46.86
Market: Euroswiss									
Call 2A	72.634**	3128.722**	72.634**	3128.722**	Put 2A	−123.201**	900.875**	−123.201**	900.875**
Call 2B	631.667	1520.845	631.667	1520.845	Put 2B	−178.718	723.383	−178.718	723.383
H1A	0.042*	3.586	−1.622	3.052	H1A	−0.110	2.880	−5.415	56.313**
H1B	0.254	3.681	−1.495	2.952	H1B	−0.001	2.793	−5.359	61.403
H2A	0.167*	3.655	−1.558	2.992	H2A	−0.123	2.842	−4.956	56.082**
H2B	0.364	3.746	−1.442	2.891	H2B	−0.022	2.759	−4.914	61.242
H3A	0.164	3.616	−1.548	2.943	H3A	−0.118	2.836	−5.747	57.714**
H3B	0.354	3.707	−1.438	2.843	H3B	−0.020	2.753	−5.690	62.676
H4A	0.194	3.678	−1.599	2.887	H4A	−0.105	2.824	−6.637	57.781**
H4B	0.378	3.768	−1.425	2.786	H4B	−0.010	2.741	−6.592	62.495
H5A	0.350	3.877	−1.411	2.786	H5A	−0.126	2.797	−6.164	57.517**
H5B	0.521	3.972	−1.325	2.692	H5B	−0.039	2.714	−6.057	62.409
H6A	1.088	4.738	−0.815	2.465**	H6A	−0.178	2.644	−5.681	56.573**
H6B	1.283	4.870	−0.742	2.352	H6B	−0.100	2.556	−5.136	62.064
H7A	0.013	3.630	−1.642	3.004	H7A	−0.127	2.794	−5.998	57.519**
H7B	0.201	3.727	−1.532	2.906	H7B	−0.031	2.709	−5.747	62.350
H8A	0.184	3.730	−1.507	2.910	H8A	−0.076	2.833	−5.457	56.271**
H8B	0.344	3.818	−1.419	2.814	H8B	0.009	2.749	−5.407	61.469

Return A includes TCs and margin returns whereas Return B excludes them. Call or Put 2 refers to the at-the-money option. H(x) refers to either the DN or MG hedge with rebalancing frequency x. H1 is the daily adjusted hedge, H2, H3, H4, and H5 are the second-day, third-day, weekly, and biweekly adjusted hedges, respectively. H6 is the passive hedge strategy. H7 (H8) is the ML (IV) hedging strategy. Rtn is the annualized option or hedged position return. S.D. is the standard deviation of returns. t indicates whether the paired t test for a significant difference in mean return A vs. B is significant. F indicates whether the folded F statistic testing for a significant difference in variances is significant.

* Significance at the 5% level.

** Significance at the 1% level.

Market/Option	Delta-Neutral Hedges Significant t-Tests	Delta-Neutral Hedges Significant F-Tests	Multiple-Greek Hedges Significant t-Tests	Multiple-Greek Hedges Significant F-Tests
Short Sterling Calls	23/27	15/27	3/27	5/27
Short Sterling Puts	19/27	11/27	15/27	27/27
Euromark Calls	27/27	20/27	17/27	8/27
Euromark Puts	27/27	16/27	5/27	27/27
Euroswiss Calls	8/27	10/27	3/27	4/27
Euroswiss Puts	3/27	3/27	3/27	19/27
Total	**107/162**	**75/162**	**46/162**	**90/162**

Fig. 3. Summary comparison of naked options, DN, and MG hedge returns inclusive of margin and TCs vs. exclusive returns.

parametric statistics for significant differences in means (paired t tests) and variability (F tests) is also shown in Table 1. These statistics have been estimated using the SAS PROC TTEST (SAS Institute, 1985b).[15] The forms of the paired t and the "folded" F tests are given in Eqs. (30) and (31) below.

$$\text{Paired } t \text{ statistic} = \left[\frac{(\mu_1 - \mu_2)}{\sqrt{\left(\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right)}}\right], \text{ and} \tag{30}$$

$$\text{Folded } F \text{ test} = \left[\frac{\text{Larger of } (\sigma_1^2, \sigma_2^2)}{\text{Smaller of } (\sigma_1^2, \sigma_2^2)}\right], \tag{31}$$

where μ_i is the sample mean of return series i and σ_i^2 is the sample variance of return series i.

The in-the-money and out-of-the-money results are not provided in the table[16] in the interest of brevity. However, in the interest of completeness, those results are included in the summary statistics that are detailed above in Fig. 3. The number of returns included for each of the six options in a given market are as follows: Short Sterling (4773), Euromark (3741), and Euroswiss (2451). As is shown in Table 1, and indeed is true for all 18 options, there is a significant difference between inclusive and exclusive returns for all naked options in terms of mean returns and variances (standard deviations reported) as evidenced by paired t and F tests. Interestingly, comparison of mean inclusive to exclusive returns shows that the sign of

[15] Additionally, SAS PROC UNIVARIATE (SAS Institute, 1985a) is used to test the (difference between compared) returns for normality. The Kolmogorov D statistic testing for normality rejects the hypothesis that any of the return distributions are normal. Given this, a signed rank test is used to test the hypothesis that the population mean is zero. Results of this nonparametric test for the various comparisons described in Hypotheses 1–3 show that the t tests reported here understate the level of significant differences in mean returns.

[16] These and other additional results are available from the author.

the naked option return changes from negative (for inclusive returns) to positive (for exclusive returns) in 6 of 18 cases.

Table 1 shows that there are consistent, significant differences in both t and F tests for MG hedges in Short Sterling puts. Consistent differences in mean returns are significant for DN hedges in both Euromark calls and puts. MG comparisons for F values are consistently significant for both Euromark and Euroswiss puts. Summary results for all 18 options and hedges combined as well as based on each market are provided in Fig. 3. In this figure, the results are considered significant if the k value equals 5% or less. Viewing the overall results based on the combined figures it is clear that there is a significant difference in means between inclusive and exclusive returns in a large majority (66%) of cases for DN hedges although there is none for MG hedges. Conversely, a majority of MG hedges (55.6%) yield significantly lower variances in the presence of margin and TCs while only 46.3% of these comparisons are significantly different for DN hedges. When the inclusive vs. exclusive comparison is made by market, it is clear that the highest number of significant differences is evidenced by the Short Sterling and Euromark markets for DN hedges (and to a lesser extent the MG hedges). The Euroswiss market evidences the fewest number of significant differences, which is perhaps largely due to the relatively lower number of returns in its analysis. In sum, these overall results suggest that the effect of including TCs and MRs in the return calculations produce nontrivial differences as compared to returns where these costs/returns are ignored. Thus, in all results evaluated henceforth, the analysis cites inclusive returns rather than exclusive returns.

Validation of the model proposed to account for all option and futures returns, as well as the margin and TCs, is an additional aspect of this research. It is intuitively obvious that a DN (MG) hedging approach is expected to be successful at reducing portfolio variability as compared to naked option positions. When hedging effectiveness is measured in terms of variance reduction both the DN and MG approaches are indeed effective based on the F test. For all six options in each of the three markets, all eight of the DN hedging frequencies (144 comparisons) yield highly significant F tests. Similarly, uniform variance reduction for the MG hedges is also observed for all comparisons. Given the uniformity of the F statistics, these results are not reproduced here although it is of interest to report the extent to which option-only variability is eliminated through hedging on average. Accordingly, the average S.D. of returns for all naked options is calculated to be 1360%, whereas the average S.D. for all DN hedges is 3%. Based on these averages, the average reduction in return S.D. achieved through DN hedging is found to be 99.78%. Thus, it might be said that, on average, 99.78% of naked option return variability is eliminated through DN hedging. Similar risk-reduction results are found for CG hedges. A potentially more interesting question is whether apart from risk reduction the DN or CG hedges actually improve returns. Table 2 details the results of the t tests for significant differences in naked-option means vs. hedged returns. The daily-adjusted returns are provided as these t statistics are largely representative of returns for all hedge strategies. Focusing on daily-adjusted hedges may provide a conservative portrayal of hedge returns as this strategy would tend to have the highest rebalancing TCs. As the top panel of Table 2 shows, 8 of the 18 DN-hedged means are significantly higher (or less negative) than the unhedged-option means. Conversely, in three cases, the unhedged-option

Table 2
Comparison of unhedged-option return to daily-adjusted DN and combined Greek hedge return using paired t test for difference in means

Market	Option	μ_O vs. μ_H	t statistic	Option	μ_O vs. μ_H	t statistic
DN hedges						
Short Sterling	Call 1	(−)<(−)	−0.0175	Put 1	(+)>(−)	0.9058
	Call 2	(−)<(−)	−2.0905*	Put 2	(+)>(−)	2.7470**
	Call 3	(−)<(−)	−2.5523**	Put 3	(+)>(−)	4.3515**
Euromark	Call 1	(+)>(−)	0.0731	Put 1	(−)<(+)	−4.2661**
	Call 2	(−)<(−)	−2.9635**	Put 2	(−)<(−)	−0.8551
	Call 3	(−)<(−)	−3.7674**	Put 3	(+)>(−)	1.3069
Euroswiss	Call 1	(+)>(−)	2.0657*	Put 1	(−)<(+)	−8.6825**
	Call 2	(+)>(+)	1.1456	Put 2	(−)<(−)	−6.7575**
	Call 3	(+)>(+)	0.6574	Put 3	(−)<(+)	−3.4974**
MG hedges						
Short Sterling	Call 1	(−)<(−)	−0.0085	Put 1	(+)>(+)	1.4772
	Call 2	(−)<(−)	−2.0812*	Put 2	(+)>(+)	2.4467**
	Call 3	(−)<(−)	−2.3845**	Put 3	(+)>(+)	4.3189**
Euromark	Call 1	(+)>(−)	0.0939	Put 1	(−)<(+)	−4.5253**
	Call 2	(−)<(−)	−2.9322**	Put 2	(−)<(−)	−0.5002
	Call 3	(−)<(−)	−3.7383**	Put 3	(+)>(+)	1.1638
Euroswiss	Call 1	(+)>(−)	2.0956*	Put 1	(−)<(−)	−8.6025**
	Call 2	(+)>(−)	1.1719	Put 2	(−)<(−)	−5.5937**
	Call 3	(+)>(−)	0.7121	Put 3	(−)<(−)	−3.4486**

Call 2 and Put 2 are the at-the-money options. Call 1 and Put 3 are the in-the-money options. Call 3 and Put 1 are the out-of-the-money options. μ_O vs. μ_H shows a comparison of the mean of the unhedged option to the mean of the (daily-adjusted) DN or MG hedge return. The (+) or (−) signs indicate whether the mean is greater than or less than zero. The inequality sign shows which of the two means is greater (or less negative). t Statistic shows the parametric test statistic testing for a significant difference in sample means.

* Significance at the 5% level.

** Significance at the 1% level.

mean is positive, the hedge mean is negative, and the t statistics are significant. The remaining seven comparisons do not generate significant t statistics. The bottom panel of Table 2 depicts results for the MG hedges that essentially mirror the DN results. Reference to the hedged means in Table 1 generally shows these means are quite close to zero (although this is not true for MG-hedged puts). So, the overall conclusion that may be reached regarding hedging returns is that in 44% of the cases examined here, the DN hedges transformed significant option losses into portfolio returns near zero, even after accounting for all of the costs of undertaking the hedges. In the seven cases where the mean returns compared are not significantly different, at a minimum, the hedges minimized portfolio losses.

Hypothesis 2 asserts that MG hedges should provide greater risk reduction, higher hedged means, or both, in comparison to DN hedges. The results of the parametric analysis of this hypothesis are shown in Table 3 for the at-the-money options.

Table 3
Comparison of DN to MG hedge returns

Comparison	At-the-money call			At-the-money put		
	t statistic	F statistic	Lower S.D.	t statistic	F statistic	Lower S.D.
Short Sterling						
DN H1A vs. MG H1A	2.683**	1.58**	DN	−11.384**	195.66**	DN
DN H2A vs. MG H2A	2.900**	1.36**	DN	−11.260**	202.69**	DN
DN H3A vs. MG H3A	3.228**	1.35**	DN	−10.914**	196.63**	DN
DN H4A vs. MG H4A	3.097**	1.14**	DN	−11.534**	207.52**	DN
DN H5A vs. MG H5A	3.425**	1.04	MG	−11.142**	214.66**	DN
DN H6A vs. MG H6A	3.724**	1.94**	MG	−10.141**	380.73**	DN
DN H7A vs. MG H7A	2.871**	1.52**	DN	−10.574**	200.40**	DN
DN H8A vs. MG H8A	2.774**	1.36**	DN	−11.688**	202.59**	DN
Euromark						
DN H1A vs. MG H1A	8.276**	2.09**	DN	4.807**	629.4**	DN
DN H2A vs. MG H2A	8.639**	1.73**	DN	4.384**	607.5**	DN
DN H3A vs. MG H3A	8.148**	2.27**	DN	3.896**	584.7**	DN
DN H4A vs. MG H4A	8.694**	1.64**	DN	4.772**	638.5**	DN
DN H5A vs. MG H5A	8.693**	1.54**	DN	4.218**	620.4**	DN
DN H6A vs. MG H6A	7.669**	4.62**	MG	3.882**	709.0**	DN
DN H7A vs. MG H7A	7.550**	2.47**	DN	4.657**	661.2**	DN
DN H8A vs. MG H8A	8.374**	1.98**	DN	5.031**	630.9**	DN
Euroswiss						
DN H1A vs. MG H1A	17.497**	1.38**	MG	4.658**	382.4**	DN
DN H2A vs. MG H2A	18.080**	1.49**	MG	4.260**	389.5**	DN
DN H3A vs. MG H3A	18.178**	1.51**	MG	4.822**	414.1**	DN
DN H4A vs. MG H4A	18.258**	1.62**	MG	5.590**	418.6**	DN
DN H5A vs. MG H5A	18.259**	1.94**	MG	5.191**	423.0**	DN
DN H6A vs. MG H6A	17.640**	3.70**	MG	4.811**	457.8**	DN
DN H7A vs. MG H7A	17.393**	1.46**	MG	5.048**	423.7**	DN
DN H8A vs. MG H8A	17.706**	1.64**	MG	4.728**	394.4**	DN

DN (MG) H1A is the daily-adjusted delta-neutral (multiple-Greek) hedge including all TCs/MRs. H2A, H3A, H4A, and H5A are the second-day, third-day, weekly, and biweekly adjusted hedges. H6A is the passive hedge strategy. H7A is the ML hedging strategy and H8A is the IV hedging strategy. t Statistic compares the DN hedge mean return to the corresponding MG hedge mean. Similarly, F statistic tests for a significant difference in return variances. Lower S.D. indicates whether the DN or MG hedge produces the lower standard deviation.

** Significance at the 1% level.

The form of the numerator in the t statistic is the DN mean minus the MG mean. Thus, a positive t statistic means that the DN mean is higher (or less negative) than the MG mean. All of the 48 t statistics shown in Table 3 are highly significant, although out of 144 comparisons (including the 12 options not shown), only 119 are significant. The results in Table 3 indicate that DN hedges have higher means than their MG counterparts except for Short Sterling puts. Summing all results, DN-hedged returns exceed the MG returns in 110 cases, of which 101 exhibit significant t statistics.

All of the F test statistics shown in Table 3 are highly significant except one case. Indeed, 136 comparisons of the total 144 turn out to be significant. The MG hedges consistently produce lower variances for only Euroswiss calls. The DN hedges lead to uniformly lower variances for all the puts shown in Table 3 and for most of the Short Sterling and Euromark calls. Overall, DN-hedged variances are lower in 109 cases and of these 108 are significant (including all 72 put comparisons). Based on the analysis for these three markets, the DN hedges prove to yield higher and less variable returns in a large majority of cases. Given the overall dominance of the DN hedges the remaining analysis and discussion focuses on those results.

One aspect of this analysis that may be driving these comparative results is the simple approach utilized to aggregate the partial derivatives into the MG hedge ratio suggested in the LIFFE publication. Textbook examples as in Hull (1997, Chap. 14) or Stoll and Whaley (1993, Chap. 12) suggest that for each Greek effect that is being hedged, a different option is needed to implement the hedge. Such a strategy employing numerous options would certainly lead to an increase in TCs and reduce hedge returns. Further, it would not work in the LIFFE strategy analyzed here as the base position is considered the option and the hedge asset is the futures contract.

To examine Hypothesis 3, the means and variances of the two risk-triggered hedging strategies are compared to their counterparts from the other six hedging approaches. Table 4 depicts the parametric results for the at-the-money options. The form of the numerator in the t test is the other hedge (OH) mean vs. the ML hedge mean. The t statistics for calls in all three markets are almost uniformly positive and are markedly significant for Euromark calls. Biweekly and passive other hedges have significantly higher means than ML hedges in the Short Sterling and Euroswiss markets for calls. ML hedged-put returns fare better against the other hedges for Short Sterling and the Euromark although the t tests are typically not significant. Out of all 126 comparisons, 27 are significant. ML hedge returns are higher in 40 cases, but only two of these are significant. Table 4 indicates that the ML hedging approach seems to perform better at reducing risk than generating higher returns. ML hedges provide significant variance reduction for Short Sterling and Euromark calls in most cases. In fact, the example where ML hedges offer consistently less variance reduction is for Short Sterling puts. The F statistics are significant in 57 of 126 comparisons. ML hedges yield (significantly) lower hedge variances in (39) 86 cases.

Table 5 provides the results of the parametric tests comparing IV hedges to the other hedges for the at-the-money options. The IV hedges generate mean hedge returns that are not generally significantly different from the other hedges except in comparison to the passive hedges. For calls, the other hedges typically have superior mean returns, whereas the opposite is true for puts. Of all 126 comparisons, only 17 have significant t statistics. The IV-hedged return exceeds its OH counterpart in 82 cases, with five cases being significant. Table 5 also shows that the contest for producing lower variances is a rather back-and-forth affair. The IV hedge for calls appears to be most effective at reducing risk in comparison to biweekly and passive hedges. In contrast, passive hedge returns are significantly lower than IV hedges for puts in all three markets. Overall, 44 (of 126) F statistics are significant. IV hedges generate lower variances in 49 cases and 23 cases are significant.

Table 4
Comparison of DN to ML hedge returns

Comparison	At-the-money call			At-the-money put		
	t statistic	*F* statistic	Lower S.D.	*t* statistic	*F* statistic	Lower S.D.
Short Sterling						
DN H1A vs. DN H7A	−0.831	1.06*	OH	−0.153	1.01	OH
DN H2A vs. DN H7A	0.681	1.07**	ML	−0.736	1.05	OH
DN H3A vs. DN H7A	1.412	1.05	ML	−0.974	1.05	OH
DN H4A vs. DN H7A	1.152	1.26**	ML	−0.655	1.06*	OH
DN H5A vs. DN H7A	2.547**	1.46**	ML	−0.686	1.13**	OH
DN H6A vs. DN H7A	4.590**	2.56**	ML	−2.026*	2.24**	OH
DN H8A vs. DN H7A	0.425	1.06*	ML	−0.328	1.04	OH
Euromark						
DN H1A vs. DN H7A	2.184*	1.10**	ML	−0.631	1.07*	ML
DN H2A vs. DN H7A	3.438**	1.22**	ML	−0.441	1.05	ML
DN H3A vs. DN H7A	1.774	1.05	ML	−0.284	1.05	ML
DN H4A vs. DN H7A	3.877**	1.25**	ML	−0.890	1.03	ML
DN H5A vs. DN H7A	4.274**	1.30**	ML	−0.780	1.00	OH
DN H6A vs. DN H7A	9.017**	5.33**	ML	1.231	1.23**	OH
DN H8A vs. DN H7A	3.441**	1.11**	ML	−0.031	1.05	ML
Euroswiss						
DN H1A vs. DN H7A	0.284	1.02	OH	0.210	1.06	ML
DN H2A vs. DN H7A	1.473	1.01	ML	0.041	1.03	ML
DN H3A vs. DN H7A	1.456	1.01	OH	0.104	1.03	ML
DN H4A vs. DN H7A	1.734	1.03	ML	0.268	1.02	ML
DN H5A vs. DN H7A	3.135**	1.14**	ML	0.006	1.00	ML
DN H6A vs. DN H7A	8.916**	1.70**	ML	−0.659	1.12**	OH
DN H8A vs. DN H7A	1.629	1.06	ML	0.628	1.03	ML

DN H1A is the daily-adjusted delta-neutral hedge including all TCs/MRs. H2A, H3A, H4A, and H5A are the second-day, third-day, weekly, and biweekly adjusted hedges. H6A is the passive hedge strategy. H7A is the ML hedging strategy and H8A is the IV hedging strategy. *t* Statistic compares other DN hedge mean returns to the ML hedge mean. Similarly, *F* statistic tests for a significant difference in return variances. Lower S.D. indicates whether the OH or ML hedge produces the lower standard deviation.

* Significance at the 5% level.

** Significance at the 1% level.

A risk–return measure is developed by Howard and D'Antonio (1987), which they term the HBS. This measure is used to provide further evidence on Hypothesis 3. The form of their HBS measure is given in Eq. (27) below for the relevant comparison, which is an unhedged option to a DN-hedged position.

$$\mathrm{HBS} = [(r_m + ((\mu_H - r_m)/\sigma_H)\sigma_U - \mu_U)/\sigma_U], \tag{32}$$

where $\mu_{U(H)}$ is the unhedged (hedged) portfolio mean return and $\sigma_{U(H)}$ is the unhedged (hedged) portfolio standard deviation.

Table 5
Comparison of DN to IV hedge returns

Comparison	At-the-money call			At-the-money put		
	t statistic	*F* statistic	Lower S.D.	*t* statistic	*F* statistic	Lower S.D.
Short Sterling						
DN H1A vs. DN H8A	−1.249	1.13**	OH	0.175	1.03	IV
DN H2A vs. DN H8A	0.254	1.01	IV	−0.412	1.01	OH
DN H3A vs. DN H8A	0.971	1.01	OH	−0.652	1.01	OH
DN H4A vs. DN H8A	0.736	1.18**	IV	−0.330	1.02	OH
DN H5A vs. DN H8A	2.131*	1.38**	IV	−0.355	1.09**	OH
DN H6A vs. DN H8A	4.230**	2.42**	IV	−1.667	2.15**	OH
DN H7A vs. DN H8A	−0.425	1.06*	OH	0.328	1.04	IV
Euromark						
DN H1A vs. DN H8A	−1.238	1.02	OH	−0.593	1.02	IV
DN H2A vs. DN H8A	0.082	1.10**	IV	−0.405	1.00	OH
DN H3A vs. DN H8A	−1.677	1.06	OH	−0.250	1.00	OH
DN H4A vs. DN H8A	0.530	1.12**	IV	−0.848	1.03	OH
DN H5A vs. DN H8A	0.956	1.17**	IV	−0.739	1.06	OH
DN H6A vs. DN H8A	6.968**	4.79**	IV	1.245	1.29**	OH
DN H7A vs. DN H8A	−3.441**	1.11**	OH	0.031	1.05	OH
Euroswiss						
DN H1A vs. DN H8A	−1.359	1.08*	OH	−0.411	1.03	IV
DN H2A vs. DN H8A	−0.171	1.04	OH	−0.583	1.01	IV
DN H3A vs. DN H8A	−0.196	1.06	OH	−0.521	1.00	IV
DN H4A vs. DN H8A	0.092	1.03	OH	−0.358	1.01	OH
DN H5A vs. DN H8A	1.518	1.08*	IV	−0.622	1.03	OH
DN H6A vs. DN H8A	7.418**	1.61**	IV	−1.299	1.15**	OH
DN H7A vs. DN H8A	−1.629	1.06	OH	−0.628	1.03	OH

DN H1A is the daily-adjusted delta-neutral hedge including all TCs/MRs. H2A, H3A, H4A, and H5A are the second-day, third-day, weekly, and biweekly adjusted hedges. H6A is the passive hedge strategy. H7A is the ML hedging strategy and H8A is the IV hedging strategy. *t* Statistic compares the other DN hedge mean returns to the IV hedge mean. Similarly, *F* statistic tests for a significant difference in return variances. Lower S.D. indicates whether the OH or IV hedge produces the lower standard deviation.

* Significance at the 5% level.

** Significance at the 1% level.

As may be readily determined, the higher the excess standardized hedged return in relation to the unhedged return and standard deviation, the higher (more positive) will be the HBS measure.

The HBS measures comparing the effectiveness of DN hedges at reducing naked-option risk are provided in Table 6. To compare the various hedging approaches to one another, for a given option, the HBS measure from each approach is ranked against the other HBS measures. These relative rankings provide information as to which hedging approach is most effective at providing the best risk–return trade-off for a particular option in each

Table 6
Comparison of ranked HBS measures for unhedged-option position vs. eight DN hedge returns including all TCs and margin returns

Option	HBS1	R1	HBS2	R2	HBS3	R3	HBS4	R4	HBS5	R5	HBS6	R6	HBS7	R7	HBS8	R8
SSC1	−1.3762	8	−1.2969	5	−1.2924	4	−1.2238	3	−1.1318	2	−0.8540	1	−1.3278	7	−1.3054	6
SSC2	−1.2188	8	−1.1087	5	−1.1071	4	−1.0126	3	−0.9103	2	−0.6366	1	−1.1648	7	−1.1209	6
SSC3	−0.9581	8	−0.8490	4	−0.8498	5	−0.7281	3	−0.6514	2	−0.4204	1	−0.8966	7	−0.8735	6
SSP1	−0.8565	3	−0.8815	4	−0.8872	6	−0.8869	5	−0.9132	7	−1.2785	8	−0.8471	1	−0.8532	2
SSP2	−0.9857	2	−1.0130	4	−1.0193	6	−1.0174	5	−1.0501	7	−1.4956	8	−0.9760	1	−1.0020	3
SSP3	−1.0628	2	−1.0873	4	−1.0981	6	−1.0933	5	−1.1310	7	−1.6429	8	−1.0615	1	−1.0741	3
EMC1	−1.2283	7	−1.1826	5	−1.1943	6	−1.1696	3	−1.0802	2	−0.7328	1	−1.2374	8	−1.1718	4
EMC2	−0.8469	8	−0.7976	5	−0.8065	6	−0.7852	4	−0.7059	2	−0.4258	1	−0.8452	7	−0.7771	3
EMC3	−0.4282	8	−0.3894	5	−0.3897	6	−0.3859	4	−0.3375	2	−0.1504	1	−0.4248	7	−0.3769	3
EMP1	−0.7735	1	−0.7935	5	−0.7912	4	−0.7903	3	−0.8100	6	−0.9369	8	−0.8219	7	−0.7803	2
EMP2	−0.9397	1	−0.9590	3	−0.9594	5	−0.9594	4	−0.9778	6	−1.0618	8	−0.9788	7	−0.9456	2
EMP3	−1.3971	1	−1.4214	4	−1.4188	3	−1.4234	5	−1.4419	6	−1.5868	8	−1.4444	7	−1.4096	2
ESC1	−1.8856	5	−1.7656	4	−1.9762	7	−1.6507	2	−1.6532	3	−0.7205	1	−2.0272	8	−1.8859	6
ESC2	−1.6199	6	−1.5013	4	−1.6698	7	−1.4741	3	−1.4331	2	−0.5677	1	−1.7503	8	−1.5788	5
ESC3	−1.1142	5	−1.0659	2	−1.2224	8	−1.1186	6	−1.0983	4	−0.4204	1	−1.1551	7	−1.0853	3
ESP1	−1.7158	1	−1.7307	4	−1.7278	3	−1.7674	5	−1.7931	6	−1.9646	8	−1.8287	7	−1.7210	2
ESP2	−2.0265	1	−2.0410	4	−2.0356	3	−2.0757	5	−2.1043	7	−2.2774	8	−2.0824	6	−2.0291	2
ESP3	−2.4852	1	−2.4969	3	−2.4999	4	−2.5337	5	−2.5647	7	−2.7817	8	−2.5428	6	−2.4894	2
Mean	−1.2733	4.22	−1.2434	4.11	−1.2748	5.17	−1.2276	4.06	−1.2104	4.44	−1.1086	4.50	−1.3007	6.06	−1.2489	3.44
S.D.	0.5111	3.04	0.5115	0.83	0.5289	1.50	0.5231	1.11	0.5457	2.25	0.7206	3.60	0.5459	2.39	0.5228	1.62

HBS(x) is the Howard and D'Antonio (1987) risk–return measure that compares the unhedged option's return and standard deviation to those of the DN hedge with the rebalancing frequency denoted as x. R(x) is the relative ranking of the HBS measure for a given option hedge. SSCz (SSPz), EMCz (EMPz), and ESCz (ESPz) is the abbreviation for Short Sterling calls (puts), Euromark calls (puts), and Euroswiss calls (puts), respectively. When $z=1$ it refers to the in-the-money call and the out-of-the-money put. $z=2$ is the at-the-money call and put. $z=3$ refers to the out-of-the-money call and the in-the-money put. S.D. is the standard deviation.

market. The HBS measures for the hedges are uniformly negative. This measure is based on the excess standardized hedge return so this is not too surprising. The notional risk-free return (r_m) used throughout the analysis is 3%, which is clearly larger than the mean return earned on many of the hedges as is shown in Table 1.

Summary statistics regarding the ranks from Table 6 show that the IV hedge approach ranks as the best HBS-based strategy with an average rank of 3.4. The weekly rebalancing frequency generates an average rank of 4.06. Based on its mean rank, the ML hedging approach comes in last place. Closer examination of Table 6 shows that the passive hedge ranks in first place for all nine calls, but ranks last for all puts. Conversely, daily rebalancing is a poor approach for hedging calls but works very well for puts. The IV hedging strategy is quite effective for puts and is modestly successful for calls.

Wilcoxon signed-rank testing is conducted for both HBS measures and rankings. The results show that IV, 2-day (DN2), and weekly (DN4) rebalanced hedges offer a significantly better risk–return trade-off vs. the 3-day (DN3) and the ML hedge (DN7) strategies based on either ranks or HBS measures. Additionally, the biweekly rebalancing approach (DN5) has significantly lower rankings and less negative HBS measures than DN7.

5. Summary and conclusions

This study examines both DN and MG hedging approaches that are popular with traders in LIFFE short-term interest rate derivative markets. To make the analysis as useful and realistic as possible, "real-world" market imperfections are explicitly incorporated into the hedging model that is developed and then tested empirically. Specifically, the portfolio-return model accounts for the impact of TCs and the costs/returns associated with initial and variation MRs. This study explicitly focuses on incorporating the daily recalculation of MRs arising from the SPAN margining system using market prices for short-term interest rate options and futures. Further, the developed model allows practitioners to determine position returns in a manner that reflects the accounting recommendations developed by LIFFE in conjunction with Price Waterhouse.

There are three principal conclusions derived from the empirical analysis. First, a comparison of returns inclusive of TCs/MRs to where they are excluded evidences statistically significant differences using parametric (and nonparametric) tests in a large number of the comparisons examined. Thus, these market imperfections may be considered nontrivial. The model is validated by analysis showing that hedged portfolio returns (variances) are significantly higher (lower) when portfolio rebalancing occurs less (more) frequently as intuition suggests.

Second, in practice, traders are concerned with position sensitivities other than just delta. An approach described in a LIFFE publication for aggregating delta, vega, theta, and gamma is employed to calculate an MG hedge ratio. All hedging effectiveness analysis is conducted for both DN and MG hedge ratios. In this analysis, DN hedges are surprisingly found to produce both significantly higher means and lower return variances in a large majority of cases compared to the more theoretically justified MG hedges.

Finally, two risk-activated hedge approaches are compared to automatically rebalanced hedges and a passive hedging strategy on the basis of mean-variance hedging effectiveness. The results of this analysis show that a DN hedging approach activated by an increase in the implied volatility of the option produces a more effective hedge on a risk–return trade-off basis than the other hedging approaches examined. Conversely, the risk-activated hedging strategy triggered by an increase in the daily ML calculated by the SPAN margining system does not prove to be an effective hedging approach. Another unexpected result is that 2-day and weekly rebalanced hedges prove significantly better than 3-day rebalanced hedges.

The primary implication of this study for future researchers is that any analysis based on the simplifying assumption of no transaction or margin costs may be seriously flawed or at a minimum may yield misleading results. Several results suggest implications for practitioners. Hedgers who are considering the use of a DN hedging approach should be impressed with the unambiguous and significant risk-reduction characteristics of all the hedging approaches analyzed. Further, the predominance of the passive hedging approach in all three call markets suggests that less frequent position rebalancing may be quite effective for calls and will certainly reduce TCs. By contrast, daily rebalancing is a commendable approach for hedging puts. Hedgers may also wish to consider increases in the implied volatility of the underlying asset as a signal for position rebalancing given its overall effectiveness here for both calls and puts. Finally, hedgers who are concerned about incorporating effects due to gamma, vega, or theta should perhaps look beyond a simple aggregation of these sensitivities into one hedge ratio.

A simplification employed here is the Black and Scholes (1973) assumption of log-normally distributed returns of the underlying asset. The appeal of this assumption is that in the model there is only one unobserved parameter, the variance of returns. Other return distributions like the jump diffusion model exists, which more accurately account for the widely recognized possibility of "fat-tails" and they may be more theoretically desirable. However, the jump diffusion model requires estimation of three unobserved parameters (Simmons, 1997, p. 26), which increases the complexity of its use. Additionally, instead of the Black (1976) European option-pricing model, a variant like the Barone-Adesi and Whaley (1987) model for an efficient analytical approximation of American option values could be used to calculate the hedging deltas and other Greeks.

One final limitation of this research is the fact that only three LIFFE short-term interest rate option and futures markets are analyzed. An interesting extension would be to analyze DN and MG hedging strategies in additional markets and different exchanges.

Acknowledgements

Thanks are due to the London International Financial Futures and Options Exchange (LIFFE) for providing price data and relevant publications and to the London Clearing House (LCH) for providing information regarding the SPAN margining system. Practical comments

regarding the implementation of the model received from Ronan O'Connor are much appreciated. Thanks for valuable comments are due to two anonymous referees, the editor, Carl R. Chen, as well as David Colwell, Stephen Figlewski, Paul Gronewoller, Martin Lally, Russell Poskitt, and Lawrence Rose. Comments from seminar participants at Massey University-Palmerston North, the 2nd New Zealand Finance Colloquium and the 11th Annual Australasian Banking and Finance Conference are also appreciated. The contribution of Kester McWeeny and my 1997 Derivative Securities class at University College Dublin in validating the original model must also be acknowledged. Finally, thanks to James Roberts for his valuable SAS programming expertise. Any remaining errors are the responsibility of the author.

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